Draft

Supplemental Environmental Impact Statement

for a

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

Summary

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250F-S1D

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ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this Repository supplemental environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

°C	degree Celsius
CFR	Code of Federal Regulations
dBA	A-weighted decibels
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
°F	degree Fahrenheit
FEIS	Final Environmental Impact Statement [Note: This acronym may only be used when referring to the Yucca Mountain FEIS]
FR	*Federal Register*
GNEP	Global Nuclear Energy Partnership
MTHM	metric tons of heavy metal
NEPA	National Environmental Policy Act, as amended
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, as amended
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
REMI	Regional Economic Models, Inc.
RMEI	reasonably maximally exposed individual
SEIS	Supplemental Environmental Impact Statement
Stat.	United States Statutes
TAD	transportation, aging, and disposal (canister)
TSPA	Total System Performance Assessment
U.S.C.	United States Code
VdB	vibration velocity in decibels with respect to 1 micro-inch per second

TERMS AND DEFINITIONS

In this Repository SEIS, DOE has italicized terms that appear in the Glossary (Chapter 12) the first time they appear in a chapter.

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this Repository SEIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10	Negative Powers of 10
$10^1 = 10 \times 1 = 10$	$10^{-1} = 1/10 = 0.1$
$10^2 = 10 \times 10 = 100$	$10^{-2} = 1/100 = 0.01$
and so on, therefore,	and so on, therefore,
10^6 = 1,000,000 (or 1 million)	10^{-6} = 0.000001 (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are 3 chances in 1 million that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

CONVERSION FACTORS

Metric to English			English to Metric		
Multiply	by	To get	Multiply	by	To get
Area					
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. centimeter	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. centimeter
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Micrometers	0.00003937	Inches	Inches	25,400	Micrometers
Millimeters	0.03937	Inches	Inches	25.40	Millimeters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2,118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hours	Miles/hour	0.44704	Meters/second
Volume					
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1,233.49	Cubic meters
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
English to English					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion factor is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	K	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	D	0.1	=	10^{-1}
centi-	C	0.01	=	10^{-2}
milli-	M	0.0 001	=	10^{-3}
micro-	µ	0.000 001	=	10^{-6}
nano-	N	0.000 000 001	=	10^{-9}
pico-	P	0.000 000 000 001	=	10^{-12}

COVER SHEET

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

TITLE: *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS).

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ABSTRACT: DOE's Proposed Action is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. Under the Proposed Action, spent nuclear fuel and high-level radioactive waste in storage or projected to be generated at 72 commercial and 4 DOE sites would be shipped to the repository by rail (train), although some shipments would arrive at the repository by truck. The Draft Repository SEIS evaluates (1) the potential environmental impacts from the construction, operation and monitoring, and eventual closure of the repository; (2) potential long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste; (3) potential impacts of transporting these materials nationally and in the State of Nevada; and (4) potential impacts of not proceeding with the Proposed Action (the No-Action Alternative).

COOPERATING AGENCIES: Nye County, Nevada is a cooperating agency in the preparation of the Repository SEIS.

PUBLIC COMMENTS: A 90-day comment period on this document begins with the publication of the Environmental Protection Agency Notice of Availability in the Federal Register. DOE will consider comments received after the 90-day period to the extent practicable. The Department will hold public hearings to receive comments on the document at the times and locations announced in local media and the DOE Notice of Availability. Written comments may also be submitted by U.S. mail to the U.S. Department of Energy at the above address in Las Vegas, via the Internet at http://www.ymp.gov, or by facsimile at 1-800-967-0739. This public comment period and the public hearings coincide with those of the *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada – Nevada Rail Transportation Corridor* (DOE/EIS-0250F-S2D; the Nevada Rail Corridor SEIS), and *Draft Environmental Impact Statement for a Rail Alignment for the Construction and Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0369D; the Rail Alignment EIS).

FOREWORD

The U.S. Department of Energy (DOE or Department) has prepared two draft National Environmental Policy Act (NEPA) documents associated with the proposed disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository at the Yucca Mountain Site in Nye County, Nevada:

- *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS), and

- *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada – Nevada Rail Transportation Corridor* (Part 1) (DOE/EIS-0250F-S2D) (Nevada Rail Corridor SEIS) , and *Draft Environmental Impact Statement for a Rail Alignment for the Construction and Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain, Nye County, Nevada* (Part 2) (DOE/EIS-0369D) (Rail Alignment EIS).

The Repository SEIS evaluates the potential environmental impacts of constructing and operating the Yucca Mountain repository under the current repository design and operational plans, the purpose of which is to assist the U.S. Nuclear Regulatory Commission (NRC) in adopting, to the extent practicable, any EIS prepared pursuant to Section 114(f)(4) of the Nuclear Waste Policy Act, as amended (NWPA; 42 United States Code 10101 *et seq.*).

The Nevada Rail Corridor SEIS and Rail Alignment EIS evaluate the potential environmental impacts of constructing and operating a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to the repository at Yucca Mountain, the purpose of which is to help the Department decide whether to construct and operate a railroad, and if so, within which corridor and along which alignment.

Background and Context

The NWPA directs the Secretary of Energy, if the Secretary decides to recommend approval of the Yucca Mountain site for development of a repository, to submit a final EIS with any recommendation to the President. To fulfill that requirement, the Department prepared the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F, February 2002) (Yucca Mountain FEIS).

On February 14, 2002, the Secretary transmitted to the President his recommendation (including the Yucca Mountain FEIS) for approval of the Yucca Mountain site for development of a geologic repository. The President considered the site qualified for application to the NRC for construction authorization and recommended the site to the U.S. Congress. Subsequently, Congress passed a joint resolution of the U.S. House of Representatives and the U.S. Senate designating the Yucca Mountain site for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. On July 23, 2002, the President signed the joint resolution into law (Public Law 107-200). The Department is now in the process of preparing an application for submittal to the NRC seeking authorization to construct the repository, as required by the NWPA (Section 114(b)).

Since completion of the Yucca Mountain FEIS in 2002, DOE has continued to develop the repository design and associated construction and operational plans. As now proposed, the newly designed surface and subsurface facilities would allow DOE to operate the repository following a primarily canistered approach in which most commercial spent nuclear fuel would be packaged at the reactor sites in transportation, aging, and disposal (TAD) canisters. Any commercial spent nuclear fuel arriving at the repository in packages other than TAD canisters would be repackaged by DOE at the repository into TAD canisters. DOE would construct the surface and subsurface facilities over a period of several years (referred to as phased construction) to accommodate an increase in spent nuclear fuel and high-level radioactive waste receipt rates as repository operational capability reaches its design capacity. To address the current repository design and operational plans, the Department announced its intent to prepare a Supplement to the Yucca Mountain FEIS (DOE/EIS-0250F-S1), consistent with NEPA and the NWPA. (*Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV*; 71 FR 60490, October 13, 2006). The Repository SEIS supplements the Yucca Mountain FEIS by considering the potential environmental impacts of the construction, operation and closure of the repository under the current repository design and operational plans, and by updating the analysis and potential environmental impacts of transporting spent nuclear fuel and high-level radioactive waste to the repository, consistent with transportation-related decisions the Department made following completion of the Yucca Mountain FEIS.

On April 8, 2004, the Department issued a Record of Decision announcing its selection, both nationally and in the State of Nevada, of the mostly rail scenario analyzed in the Yucca Mountain FEIS as the primary means of transporting spent nuclear fuel and high-level radioactive waste to the repository (*Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV*; 69 FR 18557, April 8, 2004). Implementation of the mostly rail scenario ultimately would require the construction of a rail line to connect the repository site at Yucca Mountain to an existing rail line in the State of Nevada. To that end, in the same Record of Decision, the Department also selected the Caliente rail corridor from several corridors considered in the Yucca Mountain FEIS as the corridor in which to study possible alignments for a rail line. On the same day DOE selected the Caliente corridor, it issued a Notice of Intent to prepare an EIS under NEPA to study alternative alignments within the Caliente corridor (the Rail Alignment EIS; DOE/EIS-0369) (*Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*; 69 FR 18565, April 8, 2004).

During the subsequent public scoping process, DOE received comments suggesting that other rail corridors be considered, in particular, the Mina route. In the Yucca Mountain FEIS, DOE had considered but eliminated the Mina route from detailed study because a rail line within the Mina route could only connect to an existing rail line in Nevada by crossing the Walker River Paiute Reservation, and the Tribe had informed DOE that it would not allow nuclear waste to be transported across the Reservation.

Following review of the scoping comments, DOE held discussions with the Walker River Paiute Tribe and, in May 2006, the Tribal Council informed DOE that it would allow the Department to consider the potential impacts of transporting spent nuclear fuel and high-level radioactive waste across its reservation. On October 13, 2006, after a preliminary evaluation of the feasibility of the Mina rail corridor, DOE announced its intent to expand the scope of the Rail Alignment EIS to include the Mina corridor (*Amended Notice of Intent to Expand the Scope of the Environmental Impact Statement for the Alignment,* *Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*; 71 *FR* 60484). Although the expanded NEPA analyses, referred to as the Nevada Rail Corridor SEIS and Rail Alignment EIS, evaluate the potential environmental impacts associated with the Mina corridor, DOE has identified the Mina alternative as non-preferred because the Tribe has withdrawn its support for the EIS process.

Relationships among the EISs

The Yucca Mountain FEIS, the Repository SEIS and the Nevada Rail Corridor SEIS and Rail Alignment EIS are related in several respects. The Nevada Rail Corridor SEIS, supplements the rail corridor analysis of the Yucca Mountain FEIS by analyzing the potential environmental impacts associated with constructing and operating a railroad within the Mina corridor. The Nevada Rail Corridor SEIS analyzes the Mina corridor at a level of detail commensurate with that of the rail corridor analysis in the Yucca Mountain FEIS, and concludes that the Mina corridor warrants further study in the Rail Alignment EIS to identify an alignment for the construction and operation of a railroad.

The Nevada Rail Corridor SEIS also updates relevant information regarding three other rail corridors previously analyzed in the Yucca Mountain FEIS (Carlin, Jean, and Valley Modified). The update demonstrates that there are no significant new circumstances or information relevant to environmental concerns associated with these three rail corridors, and that they do not warrant further consideration in the Rail Alignment EIS. The Caliente-Chalk Mountain rail corridor, which also was included in the Yucca Mountain FEIS, would intersect the Nevada Test and Training Range, and was eliminated from further consideration because of U.S. Air Force concerns that a rail line within the Caliente-Chalk Mountain corridor would interfere with military readiness testing and training activities.

The Rail Alignment EIS tiers from the broader corridor analysis in both the Yucca Mountain FEIS and the Nevada Rail Corridor SEIS, consistent with the Council on Environmental Quality regulations (see 40 Code of Federal Regulations 1508.28). Under the Proposed Action considered in the Rail Alignment EIS, DOE analyzes specific potential impacts of constructing and operating a rail line along common segments and alternative segments within the Caliente and Mina corridors for the purpose of determining an alignment in which to construct and operate a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to a geologic repository at Yucca Mountain.

The Repository SEIS includes the potential environmental impacts of national transportation, and the potential impacts from the construction and operation of a rail line along specific alignments in either the Caliente or the Mina corridor, as described in the Rail Alignment EIS to ensure that the Repository SEIS considers the full scope of potential environmental impacts associated with the proposed construction and operation of the repository. Conversely, the Rail Alignment EIS includes the potential impacts of constructing and operating the repository as a reasonably foreseeable future action in its cumulative impacts analysis. To ensure consistency, the Repository SEIS, and the Nevada Rail Corridor SEIS and Rail Alignment EIS use the same inventory of spent nuclear fuel and high-level radioactive waste and the same number of rail shipments for analysis. Thus, the associated occupational and public health and safety impacts within the Nevada rail corridors under consideration are the same in both documents. Furthermore, to promote conformity, where appropriate, consistent analytical approaches were used in both documents to evaluate the various resource areas.

Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS-0250F)

Proposed Action:

- DOE would construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain.
- Repository operations would include transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain nationally and in Nevada by either mostly rail or mostly truck

Record of Decision

- Mostly rail nationally and in Nevada
- Caliente rail corridor to determine alignment

Repository SEIS (DOE/EIS-0250F-S1)

1. Supplements the Yucca Mountain FEIS in its entirety, as modified by:
   - Record of Decision (mostly rail, Caliente corridor) (69 FR 18557)
   - Outcome of the Nevada Rail Corridor SEIS (Mina corridor)
2. Otherwise Proposed Action remains unchanged:
   - DOE would construct, operate and monitor, and eventually close a repository
   - During repository operations, shipments would occur by mostly rail
   - In Nevada, rail shipments would occur on a railroad to be constructed along an alignment within either Caliente or Mina corridors
   - Shipments also would arrive at repository by truck
3. To supplement Nevada transportation analysis, Repository SEIS will incorporate by reference relevant information from the Rail Alignment EIS:
   - Affected environments of Caliente and Mina rail alignments
   - Environmental impacts from constructing and operating a railroad along Caliente or Mina alignment
   - Cumulative impacts associated with Caliente and Mina alignments

Nevada Rail Corridor SEIS (Part 1) (DOE/EIS-0250F-S2)

1. Supplements the Nevada transportation analysis of Yucca Mountain FEIS, as modified by:
   - Record of Decision (mostly rail) (69 FR 18557)
   - Proposed consideration of Mina corridor
2. Under the Proposed Action, DOE would construct and operate a railroad to connect the Yucca Mountain repository to an existing rail line near Wabuska, Nevada (the Mina corridor)
   - Mina corridor information and analyses to be at level of detail commensurate with that of the other corridors in the Yucca Mountain FEIS
3. Consider other corridors in Yucca Mountain FEIS for significant new circumstances or information relevant to the environmental concerns
   - Review environmental information available since Yucca Mountain FEIS
4. Conclusion:
   - Whether the Mina corridor warrants further detailed study to determine an alignment based on impact analysis
   - Whether there are significant changes or new information relevant to environmental concerns for the other corridors that would warrant further detailed study to determine an alignment

Rail Alignment EIS (Part 2) (DOE/EIS-0369)

1. The Rail Alignment EIS tiers from the Yucca Mountain FEIS and Nevada Rail Corridor SEIS
2. Proposed Action based on Record of Decision (69 FR 18557)
   - Under Proposed Action, DOE would determine an alignment for the construction and operation of a railroad
     - ⇒ Caliente Implementing Alternative (preferred)
     - ⇒ Mina Implementing Alternative (nonpreferred)

Foreword Figure 1. Relationship among the Repository SEIS, and the Nevada Rail Corridor SEIS and Rail Alignment EIS.

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SUMMARY

S.1 Purpose and Need for Agency Action

S.1.1 WHY THE YUCCA MOUNTAIN REPOSITORY IS NEEDED

For many years, civilian and defense-related activities have produced spent nuclear fuel and high-level radioactive waste. These materials have accumulated—and continue to accumulate—at 72 commercial and 4 U.S. Department of Energy (DOE or the Department) sites across the United States. Figure S-1 shows the locations of these sites. Because these materials are highly radioactive, they must be isolated from the accessible environment. More than 25 years ago, in the *Nuclear Waste Policy Act of 1982*, Congress adopted the overwhelming consensus view in the scientific community that the best option for permanently isolating these materials would be disposing of them in a deep underground repository.

The *Nuclear Waste Policy Act* established an open, science-based, and orderly process for the identification, characterization, and approval of a site for a permanent geologic repository, and for its licensing by the U.S. Nuclear Regulatory Commission (NRC). The Act assigned lead responsibility to the Secretary of Energy. After DOE considered nine sites and recommended three for detailed evaluation, Congress amended the Act in 1987 to select Yucca Mountain as the single site for further study, and it directed the Secretary to determine whether to recommend that the President approve the Yucca Mountain site for development of a repository. (The amended Act is referred to as the NWPA.)

The Secretary's February 2002 recommendation that the President approve the site followed more than two decades of scientific investigations. As required by the NWPA, the Secretary submitted the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Yucca Mountain FEIS) with his recommendation.

On July 23, 2002, the President signed into law a joint congressional resolution designating the Yucca Mountain site for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. This action concluded the site selection process stipulated by the NWPA. As required by the NWPA, the Department is now preparing an application seeking NRC authorization to construct a repository.

S.1.2 BACKGROUND

The Proposed Action defined in the Yucca Mountain FEIS is to construct, operate, monitor, and eventually close a geologic repository at Yucca Mountain to dispose of spent nuclear fuel and high-level radioactive waste. The Proposed Action includes transportation of these materials from commercial and DOE sites to the repository.

In the Yucca Mountain FEIS, DOE considered the potential environmental impacts of a repository design for surface and subsurface facilities, a range of canister packaging scenarios and repository thermal operating modes, and plans for the construction, operation, monitoring, and eventual closure of the repository. The FEIS also described and evaluated the transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository by two principal modes—mostly truck and mostly rail. Since completion of the Yucca Mountain FEIS in 2002, the repository design

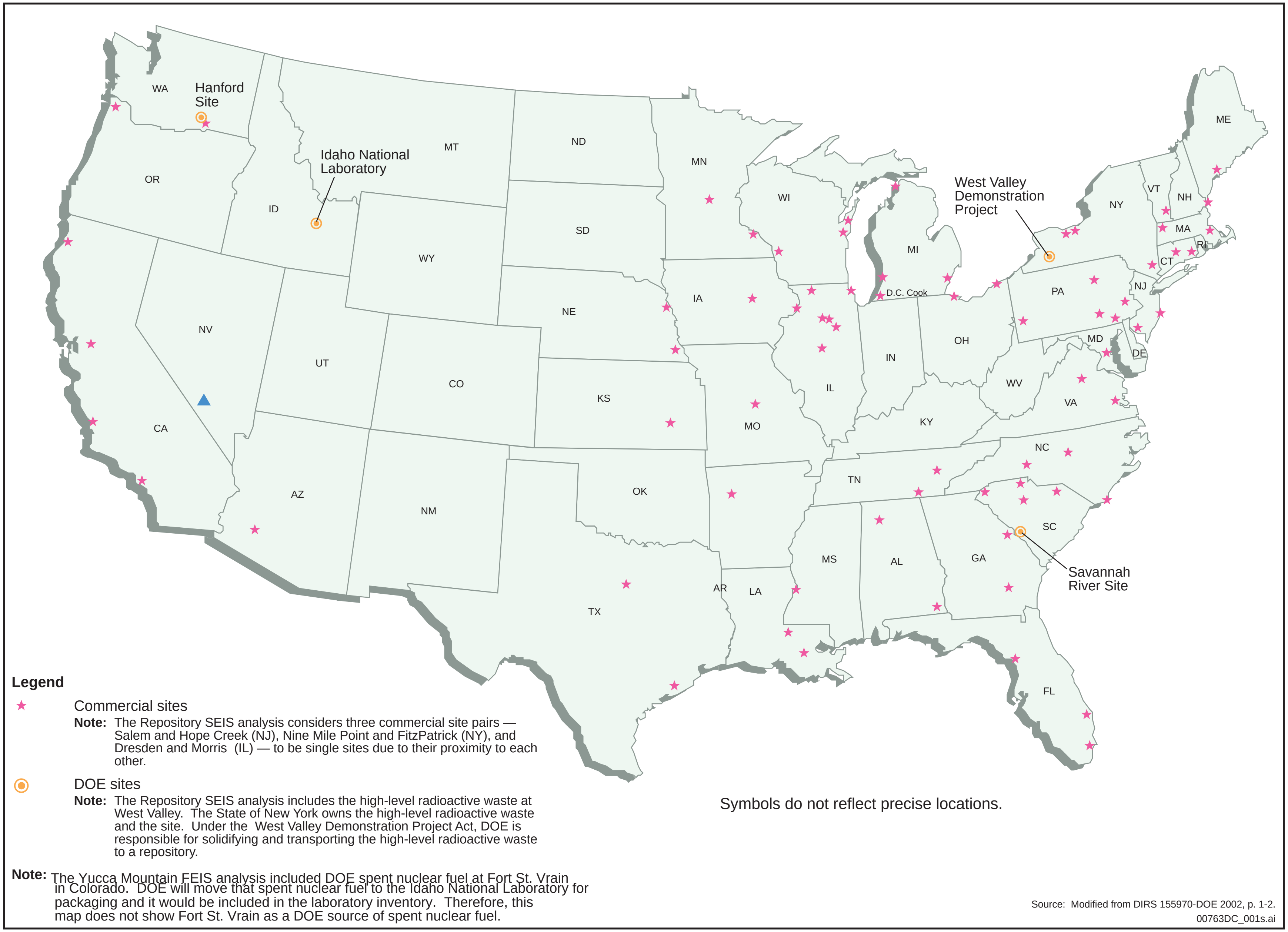


Figure S-1. Commercial and DOE sites from which DOE would ship radioactive materials to Yucca Mountain.

and associated construction and operational plans have continued to evolve, and additional information and updated analytic tools relevant to estimating potential environmental impacts have become available.

The repository design and associated plans now include the construction of up to eight waste handling facilities over a period of several years, whereas in the Yucca Mountain FEIS DOE envisioned a single waste handling building and associated facilities to be constructed at one time. The details of the infrastructure required for construction and operations (access road, power lines, and support facilities) have matured since the FEIS and are now sufficient to allow a more detailed analysis. DOE would now operate the repository following a primarily canistered approach in which most spent nuclear fuel and high-level radioactive waste would be packaged at the reactor and DOE sites in canisters suitable for transport to, and aging and disposal at, the repository. DOE also has announced its decision to ship most materials to the repository by rail, both nationally and within Nevada (more details can be found in Section S.2).

DOE used these current design and operational plans to develop information and data necessary to estimate potential environmental impacts for implementation of the Proposed Action in this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Repository SEIS). New estimates of land disturbance, water demand, workforce requirements, equipment emissions, materials (concrete, steel, copper) required, and quantities of each waste type (solid waste, sanitary waste) generated have been developed and used in the analyses described herein. Potential health and safety impacts have been reanalyzed using population projections to the year 2067 (as opposed to 2035 in the Yucca Mountain FEIS).

DOE also has revised the inventory of spent nuclear fuel and high-level radioactive waste to reflect the primarily canistered approach, as well as the capabilities of the commercial sites to handle truck or rail casks. A more recent model, the Total System Model, was used to evaluate these data rather than the model used in the Yucca Mountain FEIS (CALVIN). The revised inventory is reflected in the number of shipments, by truck and train, to the repository, and in the potential radiological and nonradiological impacts to workers and the public from such shipments, and from materials handling and disposal at the repository.

As part of the reanalysis of the environmental impacts throughout this Repository SEIS, the Department updated many of the analytic tools or selected new tools to estimate potential impacts. Representative rail and truck routes and the size of the population affected by these routes were determined, in part, through use of WebTRAGIS, which has been updated since 2002 (other changes relevant to transportation are discussed in Sections S.2 and S.3.3).

Potential radiological impacts to workers and the public from atmospheric releases during normal operations are now based, in part, on CAP-88 rather than GENII. DOE now uses a computer model endorsed by the U.S. Environmental Protection Agency (EPA), AERMOD, rather than ISC-3 to estimate nonradiological air quality impacts to workers and the public.

Potential postclosure radiological impacts to the public were developed using an updated Total System Performance Assessment Model (TSPA-SEIS). TSPA-SEIS comprises a series of updated computational models that represent the inventory, and natural and engineered barriers and their interactions to produce an estimate of a radiological dose to an individual (more details on the changes in the evaluation of postclosure performance are discussed in Section S.3.2).

This Repository SEIS also contains new analyses and updated information that result from comments received during the SEIS public scoping process. For example, DOE has included an evaluation of the potential environmental impacts that would result if (1) a higher percentage of the workforce would reside in Nye County than DOE had assumed in the Yucca Mountain FEIS, and (2) a lower percentage of commercial spent nuclear fuel were received at the repository in transportation, aging, and disposal canisters than the percentage DOE had used as a planning basis.

DOE is issuing this draft Repository SEIS now to give the public an opportunity to comment on the potential impacts associated with the repository design and operational plans that DOE intends to include in the application for construction authorization it will file with NRC. The NWPA directs that, if NRC authorizes DOE to construct a repository, it is to adopt, to the extent practicable, "[a]ny environmental impact statement prepared in connection with a repository proposed to be constructed by the Secretary ..."

S.1.3 COOPERATING AGENCY

Council on Environmental Quality regulations encourage agency cooperation early in the *National Environmental Policy Act* (NEPA) process and allow a lead agency to seek assistance from agencies that possess special expertise about issues considered in an EIS.

The Yucca Mountain site is located in Nye County, Nevada. County personnel have special expertise on the relationship of DOE's Proposed Action to the objectives of regional and local land use plans, policies, and controls, and to the county's current and planned infrastructure, including public services and traffic conditions.

Council on Environmental Quality regulations and guidance provide that agencies that accept the purpose of and need for agency action and the scope, definition, description, and analysis of it can participate as cooperating agencies in the development of the EIS. DOE invited Nye County to participate as a cooperating agency in the development of this Repository SEIS, and county personnel have contributed to it. This participation is consistent with the stated county policy of constructive engagement with DOE and with the objectives of the county's Community Protection Plan.

S.1.4 THE YUCCA MOUNTAIN SITE

The Yucca Mountain site is located in a remote area of the Mojave Desert in Nye County in southern Nevada, about 160 kilometers (100 miles) northwest of Las Vegas, Nevada (Figure S-2). DOE would build a repository inside Yucca Mountain that would consist primarily of an underground network of horizontal tunnels, called emplacement "drifts." The drifts would total about 66 kilometers (41 miles) in length and would be able to accommodate about 11,000 waste packages containing spent nuclear fuel and high-level radioactive waste. DOE would rely on the natural features of the site and on engineered barriers as a total system to help ensure the long-term isolation of the materials from the accessible environment (Figure S-3).

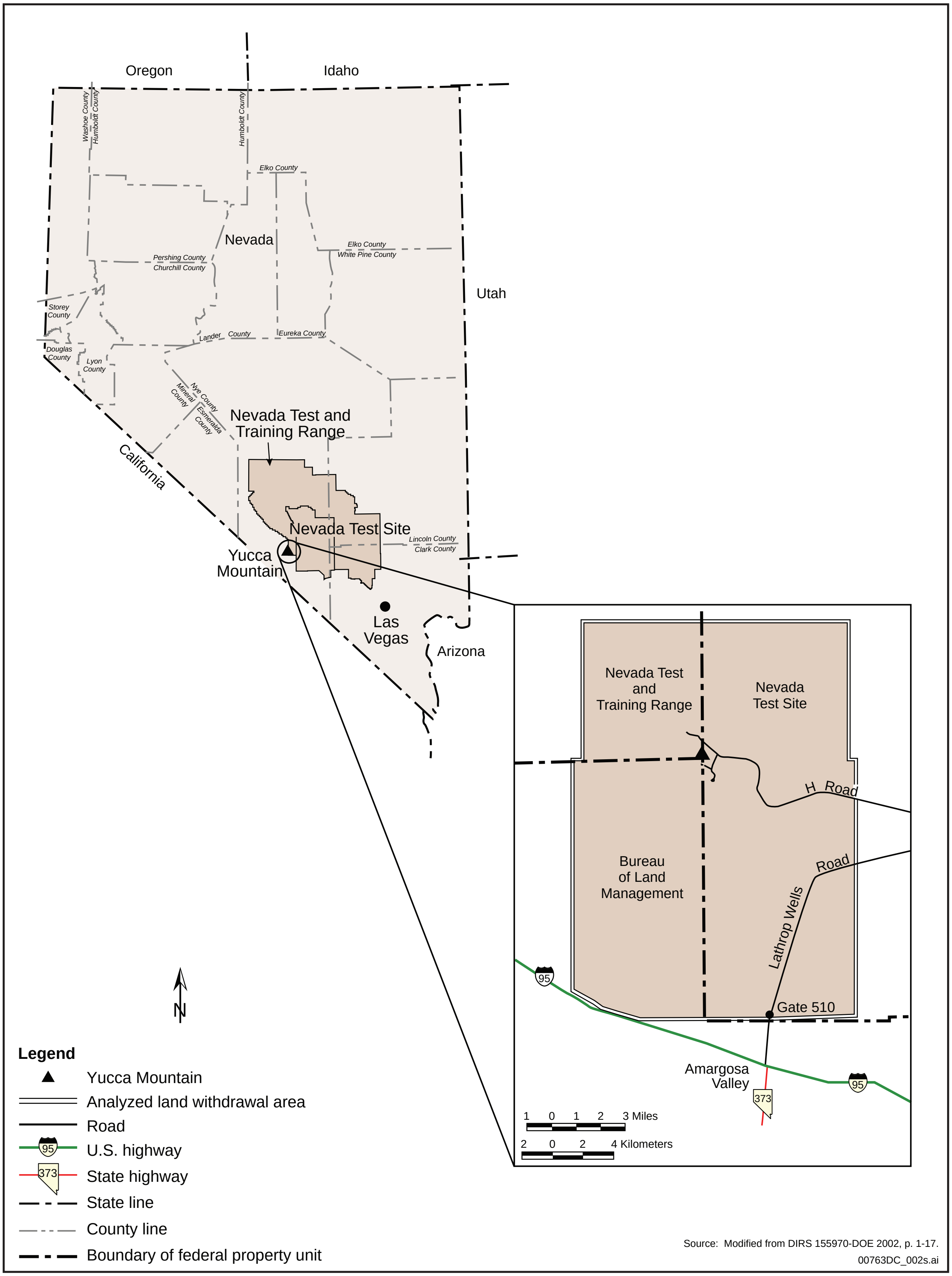
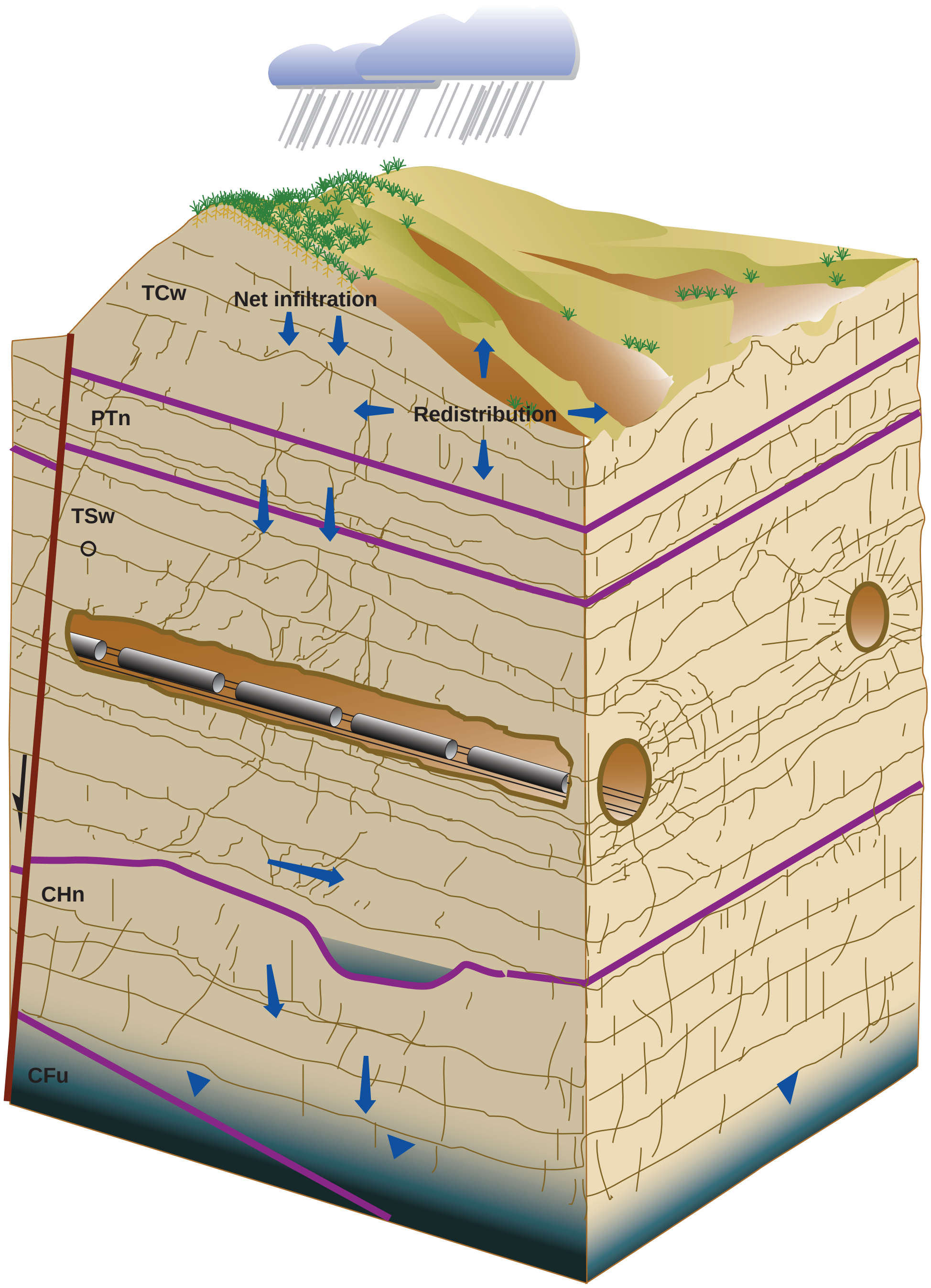


Figure S-2. Land withdrawal area used for analytical purposes.



CHn = Calico Hills nonwelded.
CFu = Crater Flat undifferentiated.
PTn = Paintbrush nonwelded.
TCw = Tiva Canyon welded.
TSw = Topopah Spring welded.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

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Figure S-3. Components of the natural system.

The site has several characteristics that would limit potential long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. It is isolated from concentrations of human population and human activity and is likely to remain so. It is on land controlled by the Federal Government. A repository at Yucca Mountain would benefit from the arid conditions at the site—an important consideration because limiting the amount of water that reached waste packages would limit their corrosion and delay mobilization and transport of radionuclides to the accessible environment. The Yucca Mountain region is one of the driest in the United States. Little water could move through the mountain, contact waste materials, and move down to the water table. Waste packages would sit about 300 meters (1,000 feet) below the surface of the mountain and about 300 meters (1,000 feet) above the water table, a location that would further isolate them from water. Groundwater beneath Yucca Mountain flows into a “closed” hydrogeologic basin from which it cannot flow to any river or ocean. This would prevent radionuclides from spreading to other areas.

To develop a repository at Yucca Mountain, DOE would have to obtain permanent control of about 600 square kilometers (230 square miles or 150,000 acres) currently under the control of DOE, the Department of Defense (U.S. Air Force), and the Department of the Interior (Bureau of Land Management). This would require congressional action. The repository would occupy a small portion of this area, most of which would serve as a buffer zone. Because Congress has not withdrawn this land, this Repository SEIS refers to it as the analyzed land withdrawal area.

S.2 Proposed Action

The Proposed Action analyzed in this Repository SEIS is for DOE to construct, operate, monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste. Under the Proposed Action, most spent nuclear fuel and high-level radioactive waste would be shipped from 72 commercial and 4 DOE sites to the repository on trains dedicated to these shipments. Naval spent nuclear fuel would be shipped on railcars in general freight service or on dedicated trains. The balance of the shipments would be made by truck. All materials would be shipped in NRC-certified transportation casks.

At the repository, spent nuclear fuel and high-level radioactive waste, sealed in waste packages, would be emplaced underground about 300 meters (1,000 feet) below the surface and about 300 meters (1,000 feet) above the water table. The natural features of the site and the engineered barriers would work together as a total system to help ensure the long-term isolation of the materials from the accessible environment. To prevent inadvertent intrusion by and exposures to members of the public, DOE would use active institutional controls such as controlled access, inspection, and maintenance through the end of the repository closure period, after which it would use monitoring and passive institutional controls such as markers.

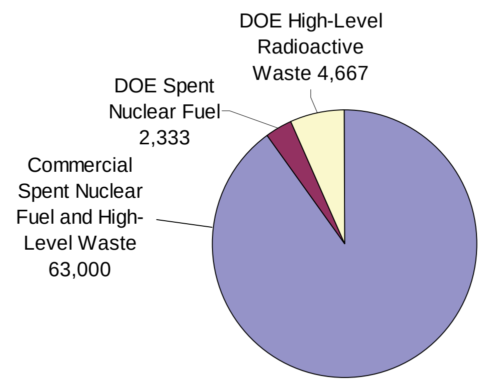
NRC, through its licensing process, would regulate repository construction, operation, monitoring, and closure.

S.2.1 MATERIALS CONSIDERED FOR DISPOSAL

The NWPA limits how much spent nuclear fuel and high-level radioactive waste DOE could emplace in the first geologic repository to 70,000 MTHM until a second repository is in operation. The materials proposed to be disposed of under the Proposed Action would include about 63,000 MTHM of commercial spent nuclear fuel and high-level radioactive waste. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel (including naval spent nuclear fuel) and the equivalent of 4,667 MTHM of DOE high-level radioactive waste.

This inventory could include surplus weapons-usable plutonium, which DOE could immobilize and dispose of as part of the high-level radioactive waste inventory, or use to produce mixed uranium and plutonium oxide fuel (called "mixed-oxide fuel"). Utilities would use the fuel to generate electricity in commercial nuclear reactors, and DOE would later dispose of that fuel as commercial spent nuclear fuel.

BREAKOUT OF INVENTORY



Values are in metric tons of heavy metal.

S.2.2 DOE'S CURRENT APPROACH TO DISPOSAL

In the Yucca Mountain FEIS, DOE evaluated the receipt of commercial spent nuclear fuel under two packaging scenarios. These include the mostly canistered scenario, in which most commercial spent nuclear fuel would be received in dual-purpose (storage and transportation) canisters, and the mostly uncanistered scenario, in which most commercial spent nuclear fuel would be received uncanistered. In the mostly canistered scenario, the dual-purpose canisters would be opened at the repository and the spent nuclear fuel repackaged into waste packages. In the mostly uncanistered scenario, spent nuclear fuel would be transferred from transportation casks to waste packages. In both scenarios, DOE would handle the fuel at the repository in an uncanistered condition prior to loading it into waste packages for emplacement. In the FEIS, all of the DOE materials (spent nuclear fuel and high-level radioactive waste) would be packaged in disposable canisters at the generator sites. These disposable canisters would not have to be opened at the repository and would be placed directly into waste packages for emplacement.

Among recent developments in repository design and operational plans is DOE's adoption of an approach to managing commercial spent nuclear fuel that would rely on a single canister design for three functions: transportation, aging, and disposal (referred to as a TAD canister). Figure S-4 shows a schematic of a TAD canister. DOE would seek NRC certification of the TAD canister design for surface storage at commercial sites and for transportation. In its application for a construction authorization, DOE would seek NRC approval to use TAD canisters for spent nuclear fuel transfer, aging, and geologic disposal at the repository. TAD canisters would not substitute for waste packages. They would be placed in waste packages for disposal, as explained below, as would all other forms of waste.

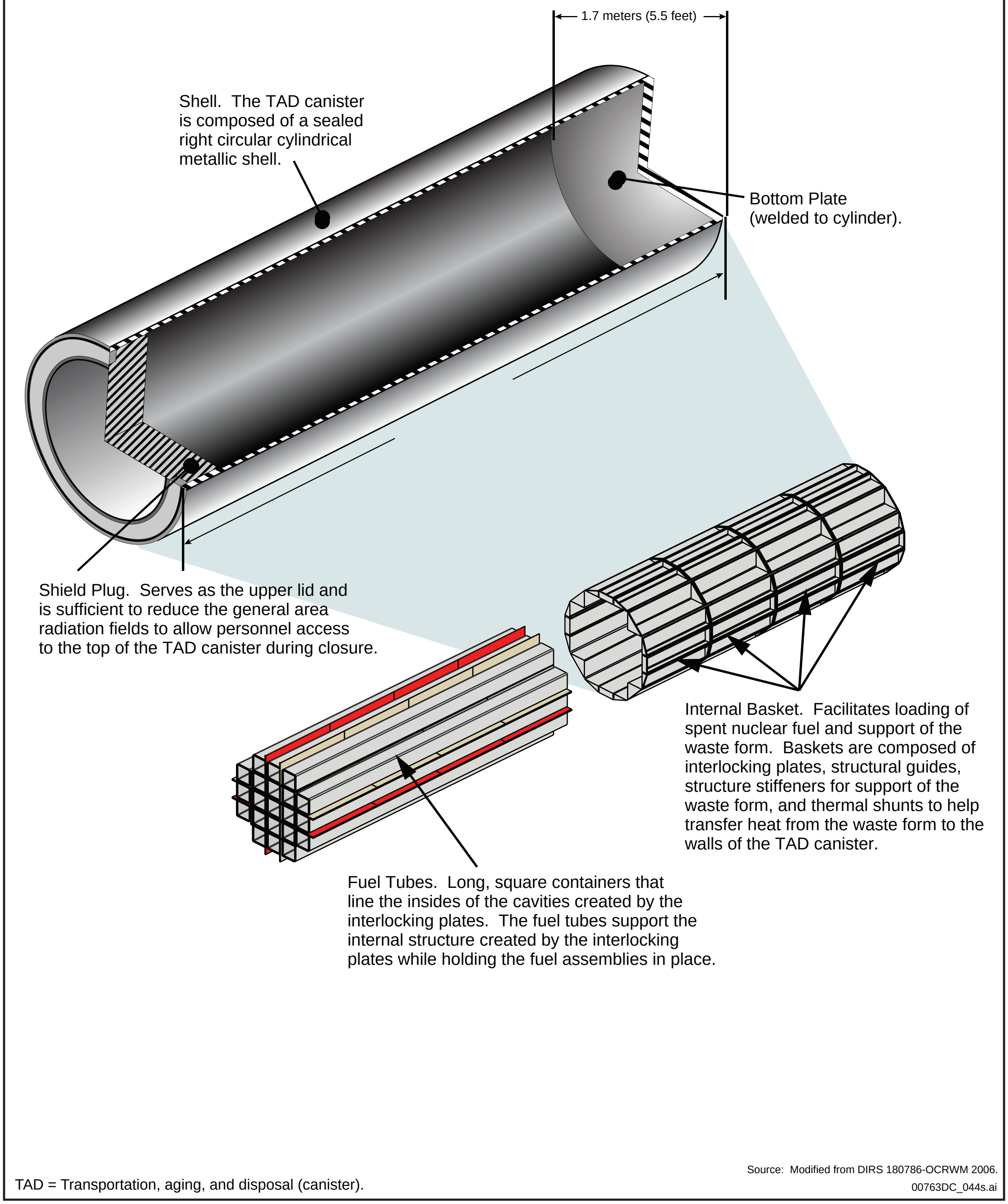


Figure S-4. TAD canister schematic (artist's concept).

At commercial reactor sites, most spent nuclear fuel (a goal of 90 percent) would be packaged in TAD canisters. Once sealed, the canisters would not have to be reopened. This would minimize the handling of individual spent fuel assemblies and limit the need for more complex repository surface facilities. Because the approach relies on practices familiar to the nuclear industry and NRC, it would simplify repository design, construction, and operation. At DOE sites, most materials destined for the repository would continue to be packaged in disposable canisters, as was the plan in the Yucca Mountain FEIS.

At the repository, some commercial spent nuclear fuel would be aged to reduce its thermal output, as part of a strategy to manage temperatures within and between emplacement drifts in order to divert water from them. Managing temperatures is important to DOE's strategy to always allow water to drain freely in the rock between the emplacement drifts. As part of this strategy, which would employ a "thermal energy density concept," DOE would place some TAD canisters into aging overpacks and place the overpacks on aging pads near the surface facilities. When heat output had declined to an appropriate level, the canisters would be placed directly into waste packages for disposal. Those TAD canisters not placed on aging pads would be placed into waste packages for disposal, as would all disposable canisters containing DOE spent nuclear fuel and high-level radioactive waste.

DEFINITIONS OF PRECLOSURE ANALYTICAL PERIODS

To evaluate the repository's potential environmental impacts through its final closure, this Repository SEIS analyzes the Proposed Action around four preclosure time periods—construction, operations, monitoring, and closure. Some activities would span more than one time period.

- **Construction: 5 years –** Begins upon DOE's receipt of construction authorization from NRC and ends with receipt of a license to receive and possess radiological materials. Activities include site preparation, surface construction, and subsurface development.
- **Operations: 50 years –** Begins upon receipt of a license to receive and possess radiological materials. Activities include receipt, handling, aging, emplacement, and monitoring of waste, as well as continued construction of surface and subsurface facilities.
- **Monitoring: 50 years** – Begins upon emplacement of the final waste package. Activities include maintaining active ventilation of the repository for as long as 50 years, remotely inspecting waste packages, and continuing investigations in support of predictions related to *postclosure* performance.
- **Closure: 10 years –** Overlaps the last 10 years of the monitoring period and includes activities that begin upon receipt of a license amendment to close the repository. Activities include decommissioning and demolishing surface facilities, emplacing drip shields, backfilling, sealing subsurface-to-surface openings, restoring the surface to its approximate condition before repository construction, and constructing monuments to mark the site.

S.2.3 REPOSITORY FACILITIES AND OPERATIONS

The handling and disposal of spent nuclear fuel and high-level radioactive waste at the repository would take place in the geologic repository operations area (Figure S-5). The surface portion of the area would include the facilities necessary to receive, package, and support emplacement of spent nuclear fuel and high-level radioactive waste in the repository. The subsurface portion would include the facilities necessary for emplacement and disposal.

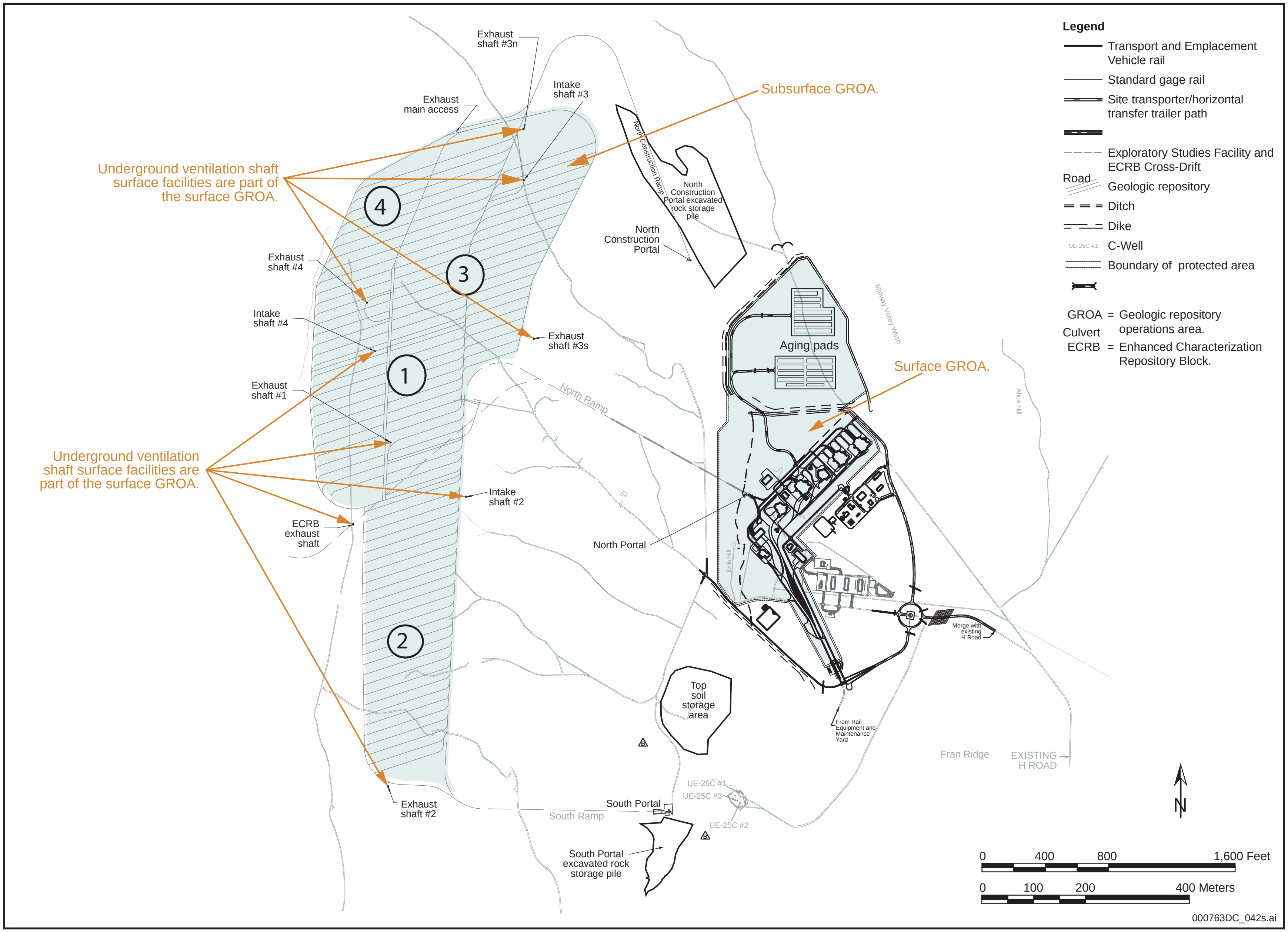


Figure S-5. Geologic repository operations area.

Figure S-6 shows how DOE would handle waste under current design and operational plans.

DOE organized its analyses of the potential impacts of the Proposed Action around preclosure (short-term) and postclosure (long-term) impacts, and it analyzed potential preclosure impacts for four time periods: repository construction, operations, monitoring, and closure.

S.2.3.1 Waste Handling Surface Facilities and Operations

The following types of surface facilities or areas would be used for waste handling: a Cask Receipt Security Station, an Initial Handling Facility, three Canister Receipt and Closure Facilities, a Wet Handling Facility, two aging pads, and a Receipt Facility.

PRIMARY FUNCTIONS OF WASTE PREPARATION AND HANDLING FACILITIES

Aging Pads: Provide the capability to age commercial spent nuclear fuel as necessary to meet waste package thermal limits.

Canister Receipt and Closure Facilities: Receive DOE disposable canisters and TAD canisters, load canisters into waste packages, and close the waste packages.

Cask Receipt Security Station: Conduct initial waste receipt and inspection.

Initial Handling Facility: Receive high-level radioactive waste and naval spent nuclear fuel canisters, load canisters into waste packages, and close the waste packages.

Receipt Facility: Transfer TAD and dual-purpose canisters, as appropriate, to the Wet Handling Facility, a Canister Receipt and Closure Facility, or the Aging Pads.

Wet Handling Facility: Handle uncanistered commercial spent nuclear fuel and open and unload dual-purpose canisters; essential purpose is loading TAD canisters.

Surface facilities would be constructed in phases. This would mean that, for several years, radiological operations would be occurring while construction of surface facilities continued. When surface construction was complete, full operational capability would be achieved. The site layout facilitates concurrent construction and operations in the geologic repository operations area.

The purpose of the waste preparation and handling facilities would be to ensure that commercial spent nuclear fuel received at the repository met waste package thermal limits, as explained below, and that all waste forms are packaged in sealed waste packages for emplacement. This would be accomplished as follows:

- Most commercial spent nuclear fuel would arrive in TAD canisters that had been loaded and sealed by the commercial nuclear utilities. Transportation casks that contained commercial spent nuclear fuel in TAD canisters that required aging, to reduce the fuel's heat output, would be unloaded in the Receipt Facility, or a Canister Receipt and Closure Facility. The TAD canisters would be transferred to aging overpacks and moved to the aging pads for thermal management. Once the thermal heat output decayed to an acceptable level, DOE would move the aging overpacks to a Canister Receipt and Closure Facility, where TAD canisters would be placed in waste packages for subsurface emplacement. TAD canisters that did not require aging would be sent directly to a Canister Receipt and Closure Facility for packaging in a waste package.

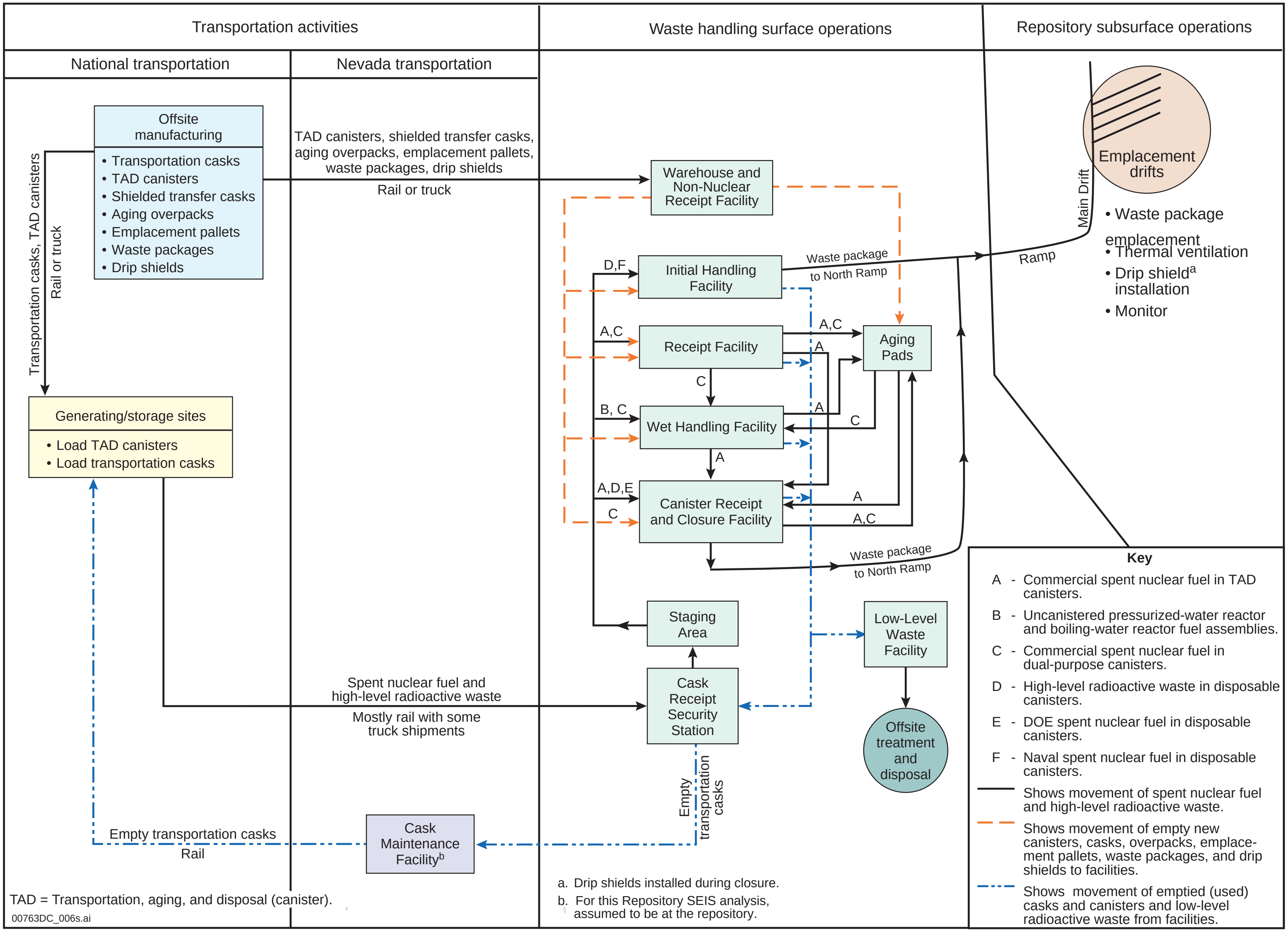


Figure S-6. Overview flowchart for typical operations of the Proposed Action.

- A small fraction of commercial spent nuclear fuel could arrive in transportation casks as uncanistered spent nuclear fuel assemblies. DOE would move these transportation casks to the Wet Handling Facility, where the fuel would be transferred to TAD canisters and subsequently managed as described above.

- Some commercial spent nuclear fuel could arrive in sealed dual-purpose canisters inside transportation casks. These canisters would be unloaded at the Receipt Facility and either be transferred to the aging pads in overpacks or transferred to the Wet Handling Facility, where they would be opened and the fuel would be transferred to TAD canisters.

- High-level radioactive waste, naval spent nuclear fuel, and DOE spent nuclear fuel would arrive at the repository in disposable canisters, inside transportation casks. Different waste types would be segregated and placed in appropriate waste packages. Casks containing naval spent nuclear fuel canisters would be unloaded in the Initial Handling Facility, where the canisters would be placed in waste packages. Casks containing DOE spent nuclear fuel would be sent directly to a Canister Receipt and Closure Facility, where the contents would be unloaded and transferred to waste packages. Casks containing high-level radioactive waste would be unloaded at either the Initial Handling Facility or a Canister Receipt and Closure Facility. High-level radioactive waste would be co-disposed with DOE spent nuclear fuel canisters. However, a naval spent nuclear fuel canister would be placed in a waste package by itself.

DOE would conduct waste transfer operations in these facilities using mostly remotely operated equipment. Thick, reinforced concrete shield walls, shielded canister transfer, and controlled access techniques would protect workers from radiation exposure. DOE would use a site transportation network to move transportation casks and waste packages between the waste handling facilities and eventually to the subsurface facility.

S.2.3.2 Subsurface Facilities and Operations

Once the various types of wastes received at the repository were sealed in waste packages, the waste packages would be transferred to the subsurface portion of the geologic repository operations area.

The subsurface facilities would consist of a main drift that would provide access to smaller, dedicated drifts into which the waste would be placed. Emplacement drifts would be excavated horizontally in a series of four emplacement panels that would be developed and made operational over a period of years coinciding with the schedule for receipt of waste (Figure S-5).

Under the current repository design, the area required to accommodate 70,000 MTHM totals about 6 square kilometers (1,500 acres), with approximately 66 kilometers (41 miles) of emplacement drifts. About 11,000 waste packages and their emplacement pallets would be placed in these drifts. DOE would use tunnel boring machines to excavate the drifts.

The waste package and emplacement pallet are two of the engineered barriers that would contribute to waste containment and isolation. Waste packages would be supported on emplacement pallets and aligned end-to-end on the drift floor. Figure S-7 shows emplacement pallets loaded with waste packages in an emplacement drift. The waste packages would consist of two concentric cylinders. The inner cylinder would be made of Stainless Steel Type 316, and the outer cylinder would be made of

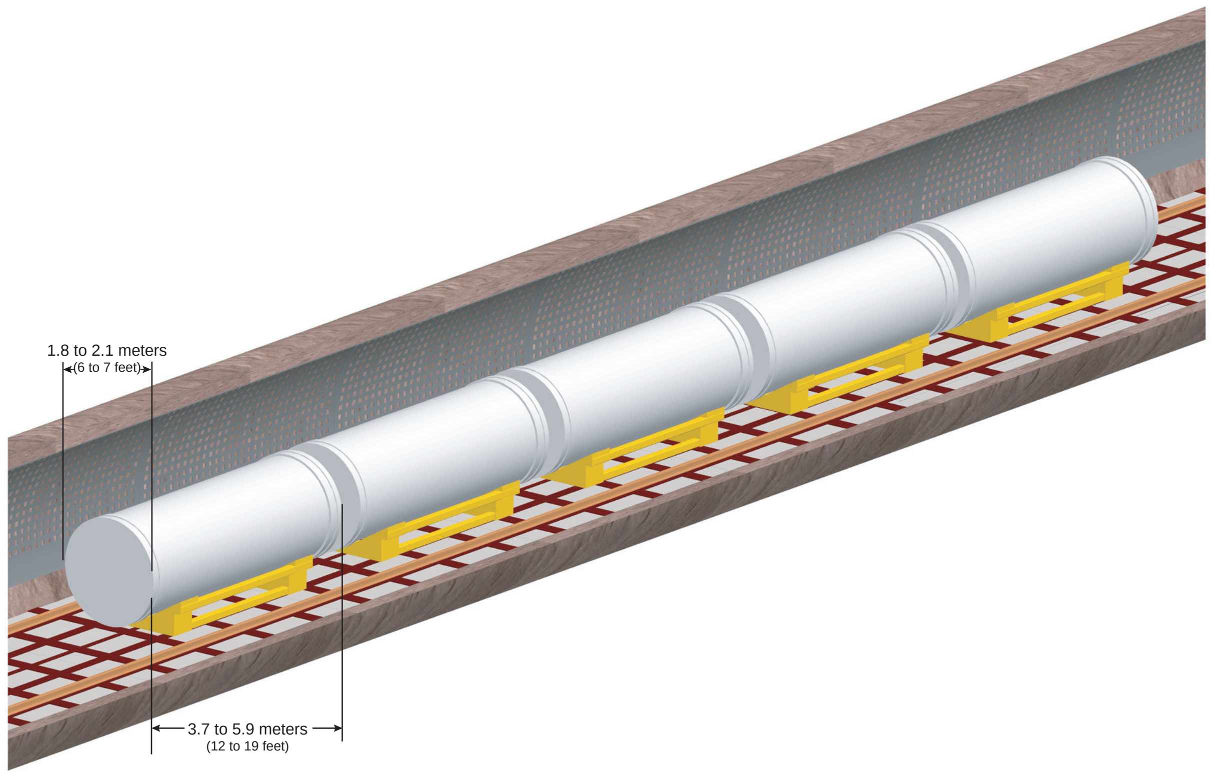


Figure S-7. Emplacement pallets loaded with waste packages in an emplacement drift (artist's concept).

corrosion-resistant, nickel-based Alloy 22. Emplacement pallets would be fabricated from Alloy 22 plates and stainless steel. The current waste package design differs only in minor ways from that in the Yucca Mountain FEIS.

DEFINITIONS OF PACKAGING TERMS

Aging overpack: A cask specifically designed for aging spent nuclear fuel. TAD canisters and dual-purpose canisters would be placed in aging overpacks for aging on the aging pads.

Disposable canister: A metal vessel for DOE spent nuclear fuel assemblies (including naval spent nuclear fuel) or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, DOE would remove the disposable canister from the transportation cask and place it in a waste package. There are a number of types of disposable canisters, including standard canisters, multicanister overpacks, and TAD canisters.

Dual-purpose canister: A metal vessel suitable for storing (in a storage facility) and shipping (in a transportation cask) commercial spent nuclear fuel assemblies. At the repository, DOE would remove dual-purpose canisters from the transportation cask, open them, remove the spent nuclear fuel assemblies, and place them in a TAD canister, which would be placed in a waste package. The opened canister would be recycled or disposed of off the site as low-level radioactive waste.

Uncanistered spent nuclear fuel: Commercial spent nuclear fuel placed directly into transportation casks. At the repository, DOE would remove spent nuclear fuel assemblies from the transportation cask and place them in a TAD canister, which would be placed in a waste package or site aging overpack.

Shielded transfer cask: A metal vessel used to transfer canisters between waste handling facilities.

Transportation, aging, and disposal (TAD) canister: A canister suitable for storage, shipping, and disposal of commercial spent nuclear fuel. Commercial spent nuclear fuel would be placed in a TAD canister at the commercial reactor. At the repository, DOE would remove the TAD canister from the transportation cask and place it in a waste package or an aging overpack. The TAD canister is one of a number of types of disposable canisters.

Transportation cask: A vessel that meets regulatory requirements for transport of spent nuclear fuel or high-level radioactive waste via public transportation routes.

Waste package: A container that would consist of a corrosion-resistant outer container (an Alloy 22 outer cylinder and a stainless-steel inner cylinder), the waste form, and any internal containers (such as TAD canisters), spacing structure or baskets, and shielding integral to the container. Waste packages would be ready for emplacement in the repository when the outer lids were welded shut and the welds were verified to be complete.

In addition to being radioactive, spent nuclear fuel and high-level radioactive waste give off heat from radioactive decay. This is referred to as thermal energy or thermal output. When placed in a confined space, such as an emplacement drift, where heat cannot readily dissipate, these materials would heat the surrounding area. In a repository, the thermal output of the waste packages would heat the rock surrounding the emplacement drifts to a temperature higher than the boiling point of water at the repository elevation, 96° Celsius (205° Fahrenheit). This would cause the small amounts of water in the rock to turn into steam, which would move away from the drifts to a point where temperatures are below boiling. There, steam would condense back to water.

To provide a path that diverts the mobilized liquid water downward past the emplacement drifts, away from the waste packages, DOE has designed the repository to include regions between the drifts (the midpillar region) that would remain below the boiling point of water. To accomplish this, DOE would manage the thermal output of the waste packages by selecting for emplacement only those that would keep the temperature in the midpillar region below the boiling point of water, as shown in Figure S-8.

The evaluation of whether a waste package is too thermally hot for emplacement would employ a concept called *thermal energy density*, which is a measure of how heat is distributed over an area. By knowing the thermal characteristics of waste packages already emplaced in specific drifts in the repository and the thermal characteristics of waste packages available for emplacement, DOE can select those appropriate for emplacement. DOE would make the selections based on calculations of how the added thermal energy of the additional waste packages would affect the goal of maintaining the temperature of the midpillar region below the boiling point of water.

Managing an upper limit to the thermal energy density for emplacement thus would rely on selecting or blending waste packages with specific thermal characteristics. DOE would have flexibility in selecting specific waste packages for emplacement. If a waste package were too thermally hot for emplacement at the time it was received, DOE would use the aging pads to allow the thermal heat to reduce naturally through radioactive decay.

After emplacement was complete, the drifts would remain open and ventilated for a nominal period of 50 years, so ventilation would remove much of the heat and humidity from the drifts. After DOE closed and sealed the subsurface facility, the rock around the emplacement drifts would dry, further minimizing, for hundreds of years, the amount of water that could come into contact with the waste packages. A portion of the rock between the drifts would remain at temperatures below boiling, which would continue to promote drainage of water through the portions of the rock between the drifts rather than into the drifts themselves.

S.2.4 TRANSPORTATION

The Yucca Mountain FEIS considered the potential environmental impacts of transporting spent nuclear fuel and high-level radioactive waste from commercial and DOE sites by two principal modes—mostly truck and mostly rail. Since the FEIS was completed, the Department has decided to transport most spent nuclear fuel and high-level radioactive waste by rail both nationally and in Nevada. This Repository SEIS updates transportation analyses to reflect the mostly rail scenario.

DOE cannot use rail transport exclusively because some commercial nuclear generating sites do not have the ability to load large-capacity rail shipping casks. Those sites would use overweight trucks to ship material to the repository. Commercial sites that could load the rail shipping casks but lacked rail access could use heavy-haul trucks or barges to ship spent nuclear fuel to the nearest rail line. Figure S-9 shows the commercial and DOE sites and Yucca Mountain in relation to the railroad system over which the railcars could travel.

Because no rail service currently extends to the Yucca Mountain site, DOE would have to build a railroad linking the site to the terminus of an existing rail line in Nevada. As explained in the Foreword, to evaluate the potential impacts of constructing and operating a railroad in Nevada, DOE has prepared a Rail Alignment EIS that has been published coincident with this Repository SEIS. The Rail Alignment

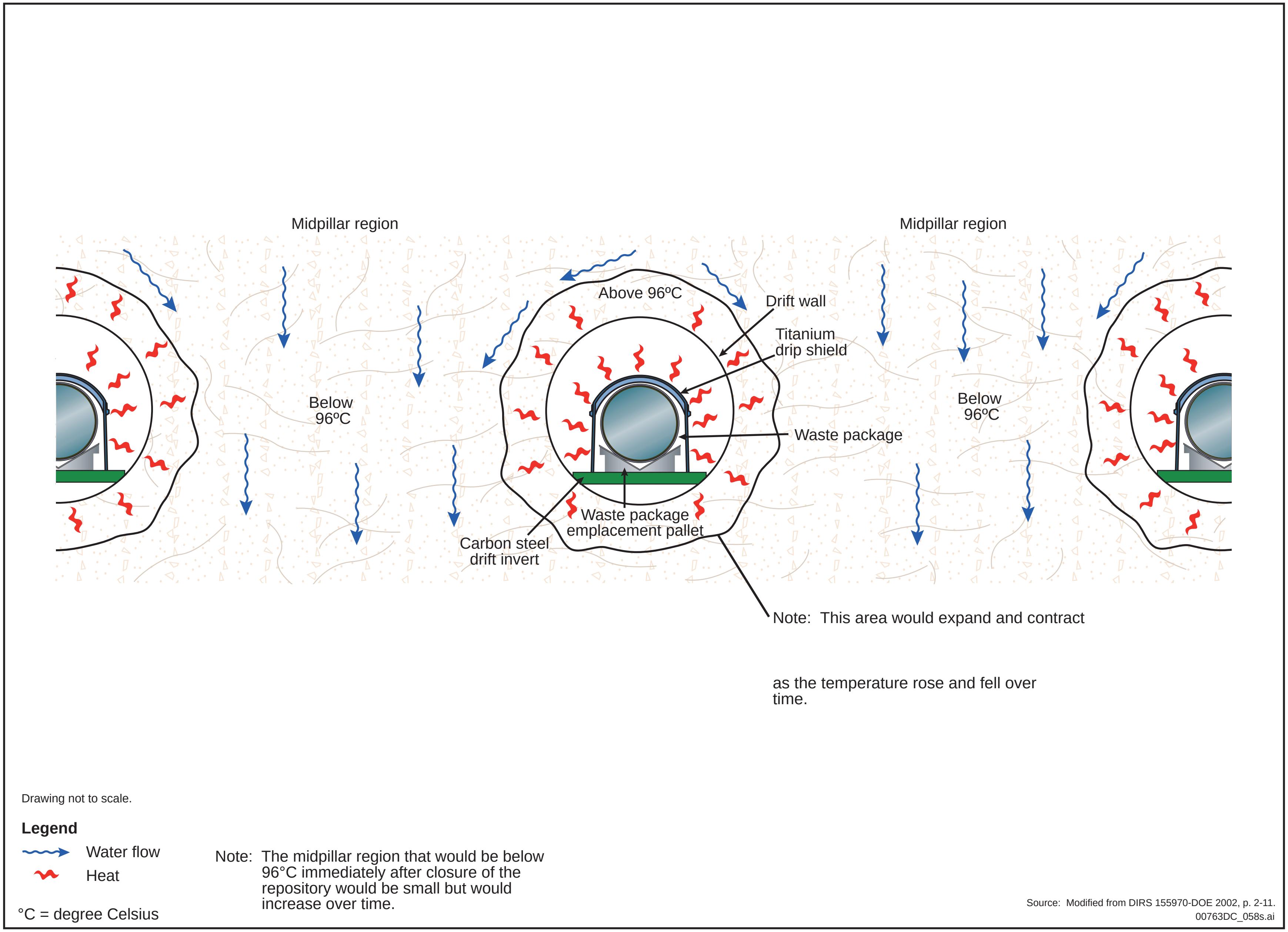


Figure S-8. Management of waste package emplacement using thermal energy density (artist's concept).

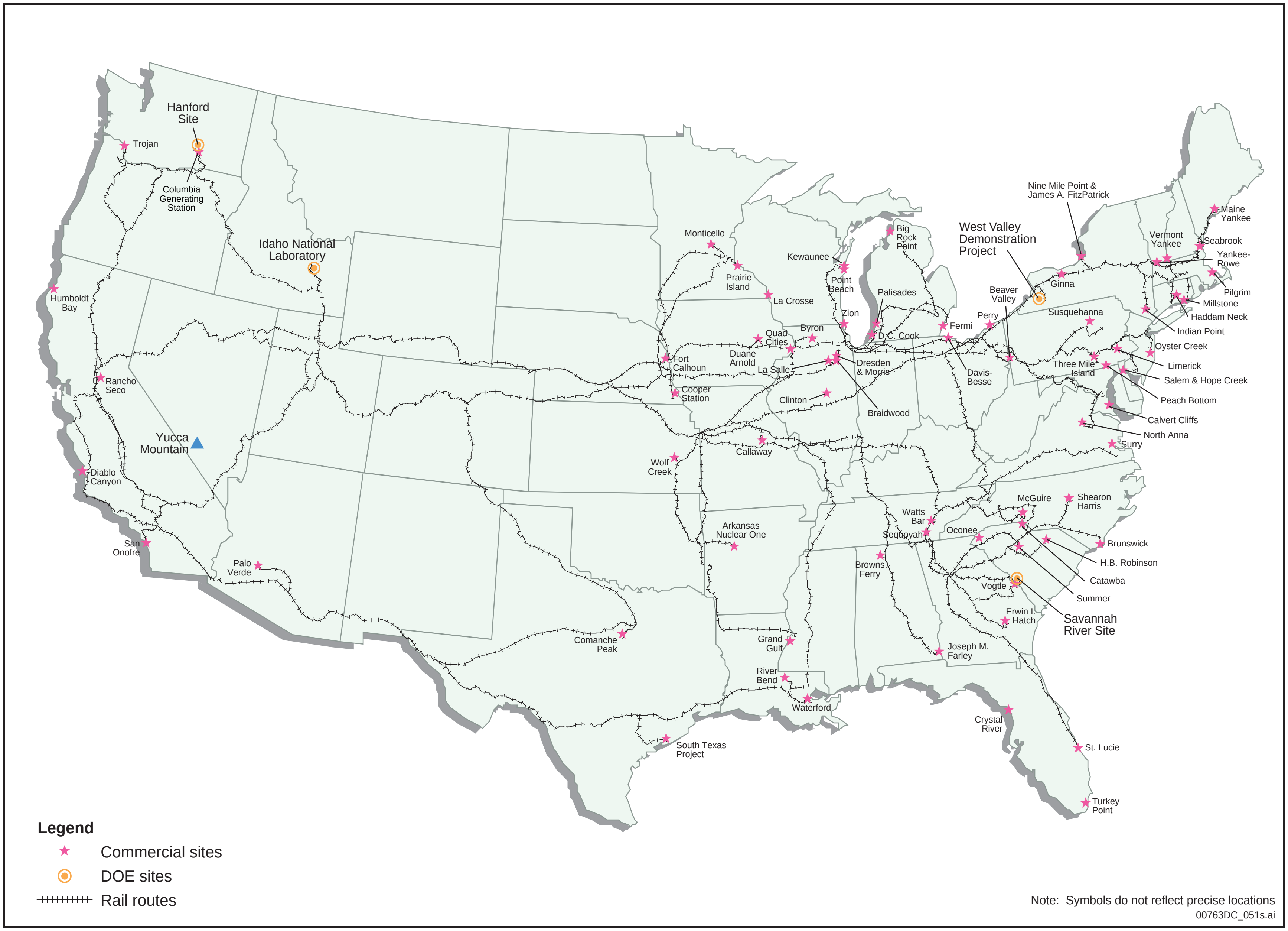


Figure S-9. Representative national rail routes considered in the analysis for this Repository SEIS.

EIS analyzes the potential impacts of constructing and operating a railroad along specific alignments in the Caliente and Mina corridors. Under the Proposed Action, DOE would determine a rail alignment in which to construct and operate a railroad for shipments of spent nuclear fuel, high-level radioactive waste, and other materials from an existing rail line in Nevada to a geologic repository at Yucca Mountain. The railroad would approach Yucca Mountain from east of U.S. Highway 95, trending generally southeast for 40 kilometers (25 miles) from Oasis Valley to Beatty Wash. It would then turn north at the southern end of Busted Butte, running west of Fran Ridge and then trending generally north for an additional 11 kilometers (7 miles) until terminating at the Rail Equipment Maintenance Yard inside the Yucca Mountain Site boundary and about 1.6 kilometers (1 mile) south of the southern boundary of the geologic repository operations area. The geologic repository operations area interface would consist of a double-track spur for delivery of casks and supplies to the surface geologic repository operations area.

The Department identifies the Caliente Implementing Alternative as its preferred alternative, and identifies its preferred rail alignment segments starting in Caliente and ending at Yucca Mountain. The Department also indicates that it prefers the Shared Use option, that is, DOE would make its rail line available to commercial shippers for shipments of general freight.

The Rail Alignment EIS also includes a No Action Alternative under which DOE would not determine an alignment or construct and operate a railroad within the Caliente or Mina rail corridors. As a general matter, the Repository SEIS summarizes and incorporates by reference information in the Rail Alignment EIS, as appropriate.

Other elements of DOE’s national transportation plan that have evolved since completion of the Yucca Mountain FEIS include the following:

- Rail shipments would be made on dedicated trains. (This policy would not apply to shipments of naval spent nuclear fuel.)
- Armed security escorts would accompany all shipments.
- Trucks carrying transportation casks could be overweight rather than legal weight. Overweight trucks would be subject to permitting requirements in each state through which they traveled.

The Yucca Mountain FEIS analyzed the shipment of about 9,600 rail casks and 1,100 truck casks under the mostly rail shipping scenario. This Repository SEIS analyzes the shipment of about 9,500 rail casks and 2,700 truck casks of spent nuclear fuel and high-level radioactive waste. The increased number of truck shipments in the Repository SEIS is primarily due to the revised information on the cask handling capabilities at commercial reactor sites. The FEIS assumed that the reactor sites that did not currently have the ability to load large rail casks would modify their facilities to obtain that ability. This SEIS does not make that assumption.

S.3 Potential Environmental Impacts of the Proposed Action

The Repository SEIS analysis of potential impacts of the Proposed Action summarizes, incorporates by reference, and updates corresponding sections of the Yucca Mountain FEIS, as appropriate. The SEIS explains where and why DOE has modified its analytic approach or assumptions and where it has updated information.

To assess potential impacts, DOE assessed baseline conditions that the current repository design and operational plans for a repository could affect. DOE organized its assessment around 12 resource areas that include features of the natural environment and matters of social, cultural, and economic concern. For each resource area, DOE defines a region of influence in which impacts could occur as a geographic area that bounds the environmental, social, cultural, and economic features of interest. Regions vary considerably because the natures of the resources vary.

DOE uses these timeframes to assess impacts:

- *Preclosure* or *short-term impacts* would encompass construction, operation, monitoring, and closure.
- *Postclosure* or *long-term impacts* would occur after closure was complete. This Repository SEIS analyzes health effects for two periods: the period during the first 10,000 years after closure and the period from 10,000 years after closure to one million years after closure (the post-10,000-year period).

DOE has characterized potential impacts as *direct* or *indirect*, and has quantified them where possible. Otherwise, it has provided qualitative assessments with these descriptors:

- *Small*. Environmental effects would not be detectable or would be so minor that they would not destabilize or noticeably alter any important attribute of the resource.
- *Moderate*. Environmental effects would noticeably alter but not destabilize important attributes.
- *Large*. Environmental effects would be clearly noticeable and would destabilize important attributes.

The potential impacts reported in this Repository SEIS are likely to be higher than the actual impacts for several reasons. For example, DOE did not take into consideration best management practices for dust suppression in the analyses for air quality, and did not take credit for proven remediation and reclamation techniques in the disturbed land analysis. Likewise, in the estimation of potential health effects in the preclosure period, DOE did not apply administrative restrictions for limiting radiological exposure in calculating potential doses to the hypothetical maximally exposed worker, who would handle spent nuclear fuel at the repository surface for an entire working lifetime of up to 50 years. Further, DOE assumed that the hypothetical maximally exposed member of the public would reside continuously for 70 years at the site boundary in the prevailing downwind direction. In the postclosure period, DOE assumed that the reasonably maximally exposed individual (who is a hypothetical individual with characteristics defined by 40 CFR Part 197) lives above the highest concentration of radionuclides in the plume of contamination and drinks 2 liters (0.5 gallon) of water per day drawn from contaminated groundwater.

S.3.1 POTENTIAL PRECLOSURE IMPACTS OF THE REPOSITORY

S.3.1.1 Land Use and Ownership

To develop a repository at Yucca Mountain, DOE would have to obtain permanent control of approximately 600 square kilometers (150,000 acres) of land now managed by the Bureau of Land Management, U.S. Air Force (Nevada Test and Training Range), and DOE (Nevada Test Site). This would require congressional action. If Congress authorized and directed the withdrawal of lands for the proposed repository, any other use of the land would be subject to conditions of the withdrawal. Because the land has not yet been withdrawn, in this Repository SEIS it is referred to as the analyzed land withdrawal area.

To analyze impacts on land use and ownership, DOE defined the region of influence as the analyzed land withdrawal area (Figure S-2) and an area to the south that DOE proposes to use for offsite facilities and a new access road from U.S. Highway 95 to the Yucca Mountain site.

The Bureau of Land Management now administers approximately 180 square kilometers (44,000 acres) of the analyzed land withdrawal area. With the exception of about 17.4 square kilometers (4,300 acres) near the site of the proposed repository and an existing patented mining claim on private land, these lands are available for public uses such as mineral exploration and recreation. Congress granted these rights under various federal laws, such as the *Federal Land Policy and Management Act of 1976*. The Bureau would evaluate and adjudicate the validity of all mining claims on the portion of the land withdrawal area that was under its control before the permanent legislative withdrawal.

To construct, operate, and monitor a repository, DOE would disturb or clear a total of approximately 9 square kilometers (2,200 acres) of land, inside and outside the analyzed land withdrawal area. Overall, impacts on land use would be small. During repository closure, DOE would restore disturbed areas that were no longer needed to their approximate condition before construction.

S.3.1.2 Air Quality

DOE analyzed potential impacts to the public from releases of nonradiological air pollutants. Air pollutants were assessed against the EPA National Ambient Air Quality Standards, which define permissible average and maximum concentration levels of pollutants for periods ranging from 1 hour to a year. DOE evaluated impacts for maximally exposed individuals at the nearest points of unrestricted public access outside the analyzed land withdrawal area. Its analysis examined five criteria pollutants—carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter (PM), for which EPA defines two particle sizes: $PM_{2.5}$, which has an aerodynamic diameter of 2.5 micrometers (about 0.0001 inch) or less in diameter, and PM_{10}, which has an aerodynamic diameter of 10 micrometers (about 0.0004 inch) or less in diameter. (DOE did not analyze the sixth criteria pollutant, lead, because repository-related activities would not emit airborne lead.) Fugitive dust from land disturbances contains PM_{10}. DOE would use common dust suppression measures to reduce releases, but did not take credit for these actions in the analyses.

DOE also analyzed potential impacts of cristobalite, a form of silica dust that causes silicosis and might be carcinogenic. Cristobalite would be emitted during subsurface excavation in fugitive dust. The highest level that would reach a member of the public would be only 0.5 percent of the benchmark DOE used in its analysis.

In all cases, the highest concentrations of criteria pollutants except PM_{10} would be less than 3 percent of applicable standards. The highest concentrations of PM_{10} from activities in the analyzed land withdrawal area would be 40 percent of the 24-hour regulatory limit during construction. Most air quality impacts would result from construction.

S.3.1.3 Hydrology

This Repository SEIS identifies and evaluates potential surface- and groundwater impacts separately, as the Yucca Mountain FEIS did. The regions of influence and criteria for evaluating impacts are the same as those in the FEIS.

S.3.1.3.1 *Surface Water*

The region of influence includes construction and operations sites susceptible to erosion, areas that could be affected by permanent changes in water flow near these sites, and downstream areas that could be affected by eroded soil or spills of contaminants. There are no perennial streams or other permanent surface-water bodies in the region of influence, and precipitation and runoff are seldom sufficient to generate flowing water in drainage channels.

During all project phases, the potential for uncontrolled or contaminated discharges to the surface would be small. DOE would store water in tanks and would pipe sanitary sewage to septic tanks and leach fields. Water used for other purposes would be collected after use and pumped to lined evaporation ponds. Water used for dust suppression would not produce runoff or infiltration. DOE would manage water contaminated with radionuclides as low-level radioactive waste. Throughout the project, DOE would manage potential contaminants in compliance with regulatory requirements and its *Spill Prevention, Control, and Countermeasures Plan for Site Activities*, and would monitor to detect contaminants.

Repository-related activities would disturb as much as 9 square kilometers (2,300 acres) of land. Because DOE would compact many surface areas or cover them with impermeable materials, infiltration rates would generally decline and surface-water runoff would increase. The increased runoff that reached drainage channels would be small and have negligible impacts, primarily because storm water detention ponds would be integral to repository design. Moreover, the total land disturbed would constitute only around 1 percent of the natural drainage area in which it would lie, and the drainage channels are so remote that minor changes in runoff could not affect downstream facilities.

S.3.1.3.2 *Groundwater*

A supply of groundwater would be essential to repository construction and operation. DOE would use most of the water to compact surface soil and suppress dust and for subsurface development. The region of influence for groundwater includes aquifers from which DOE could obtain water and the downstream aquifers that DOE's use of water could affect. The Yucca Mountain FEIS summarized DOE's efforts to obtain water rights from the State of Nevada to meet projected water needs. DOE is currently engaged in litigation with the State of Nevada with regard to these water rights.

DOE would track the volume of water it pumped to the subsurface for dust suppression and tunnel boring, and would collect the excess water and remove it. Water pumped to the subsurface probably would have little effect on aquifer recharge. No additional land disturbance would occur during monitoring and maintenance or closure, so further effects on infiltration rates would be unlikely. Soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. Overall, repository construction and operations would result in minor changes to runoff and infiltration rates.

DOE would pump groundwater from wells in the Jackass Flats hydrographic area. Groundwater from that area flows into Amargosa Desert aquifers. Because those aquifers meet most of the regional water demand, the potential effects of DOE groundwater use on this downgradient use is of particular concern.

Figure S-10 shows that water demand for the Proposed Action would peak during initial construction. The Nevada Test Site would require groundwater from Jackass Flats wells during the same period; for the peak demand years, the estimated additional demand from the Test Site would be 83,000 cubic meters (67 acre-feet). Figure S-11 does not show the Test Site use, but DOE analyzed the combined impacts and concluded in this Repository SEIS that they would not noticeably affect nearby groundwater users.

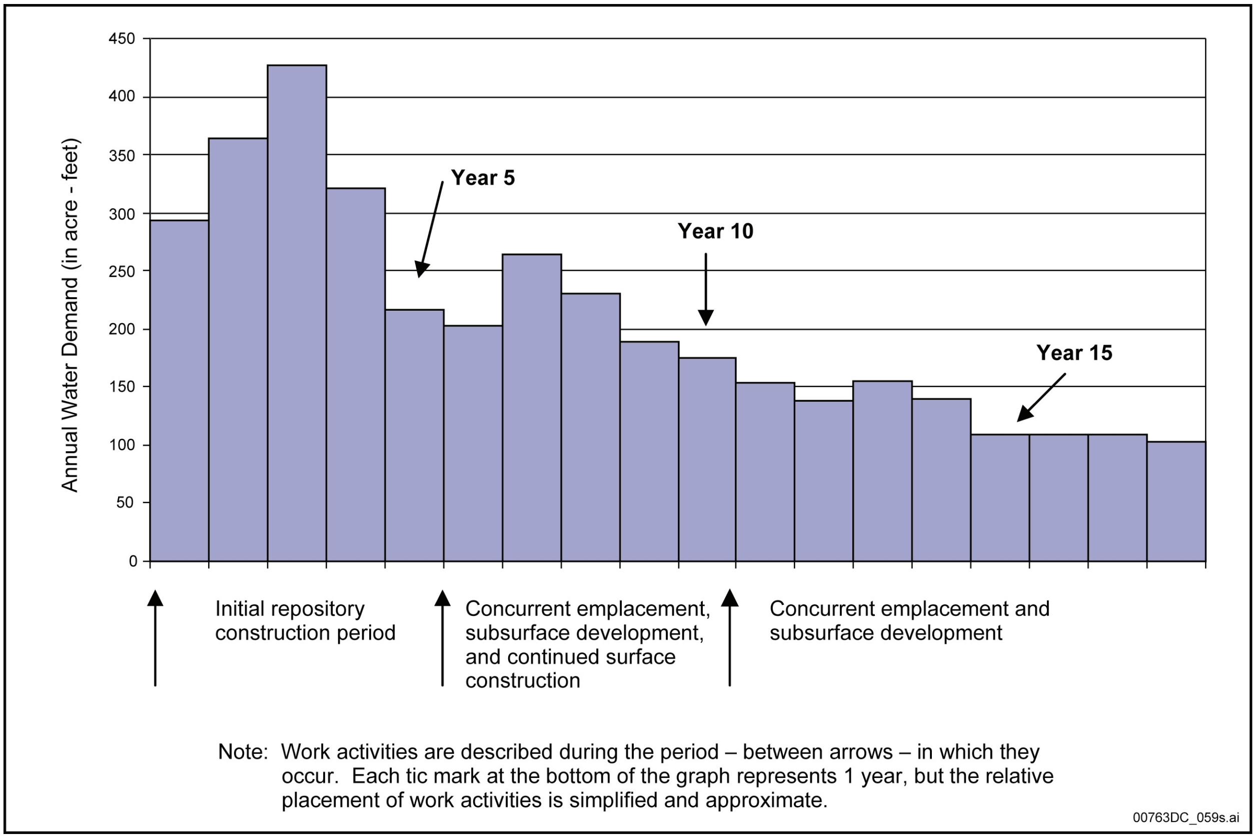


Figure S-10. Annual water demand during the repository construction period and the initial phases of operations.

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting its aquifers. The State of Nevada uses estimates of perennial yield as one of several tools in evaluating requests for groundwater appropriations. DOE's analysis focused on the following hydrographic areas:

- Jackass Flats. Estimates of perennial yield in groundwater studies and the Nevada State Engineer's rulings range from 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet), depending on assumptions about aquifer flow characteristics. In a conservative scenario, DOE's water demand is compared to the lowest estimate of perennial yield. This low estimate can be further reduced by attributing 720,000 cubic meters (580 acre-feet) to the western two-thirds of this hydrographic area

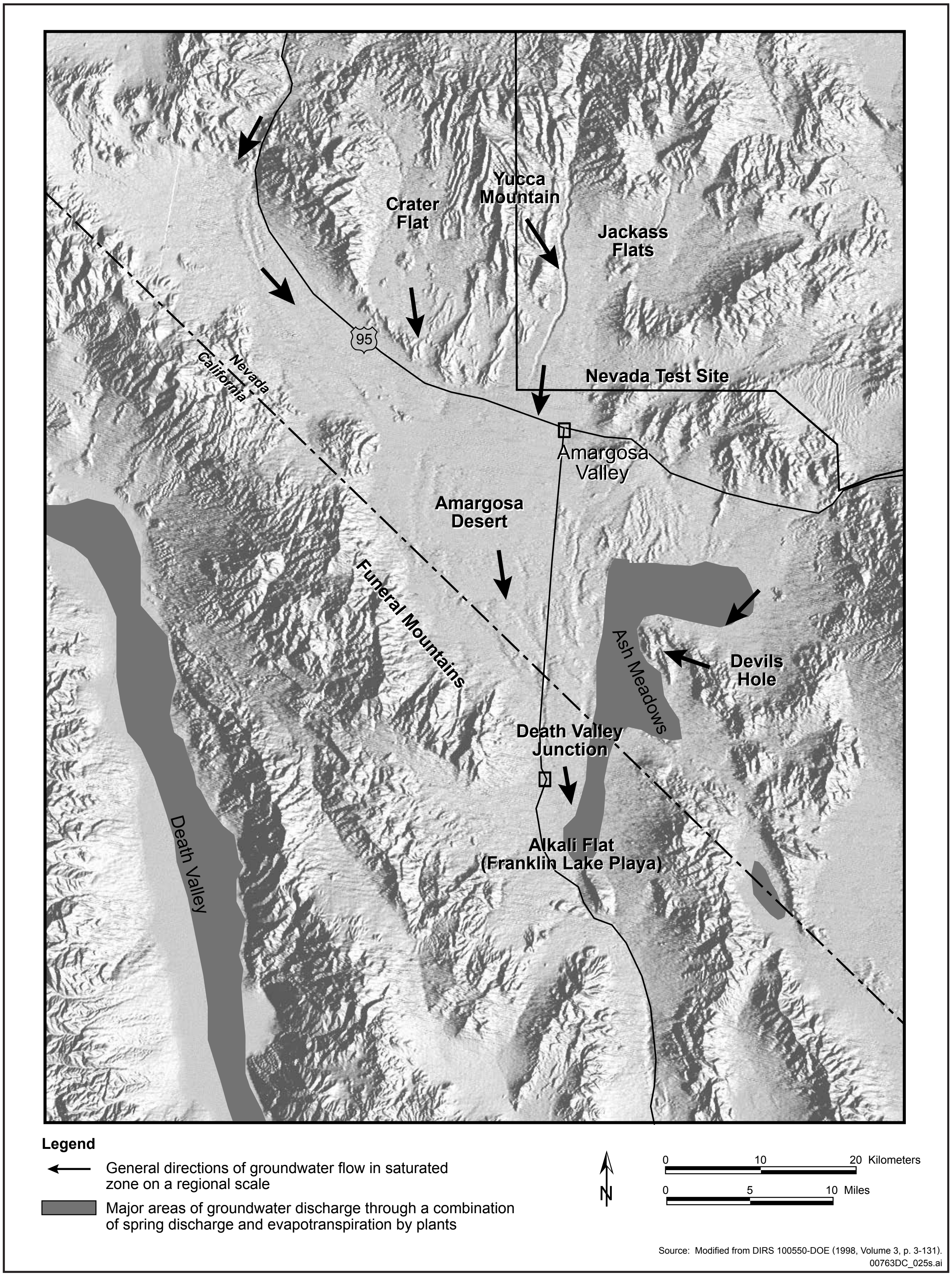


Figure S-11. Map of the saturated groundwater flow system.

where DOE's wells are located. Peak annual demand would be below the lowest estimates of perennial yield. Adding annual demand for the Nevada Test Site activities in the same hydrographic area would still result in groundwater withdrawals below the lowest estimate, and it represents only 13 percent of the highest estimate. If demand exceeded local recharge for a few years (longer durations would be unlikely), general flow patterns in the area could shift, but only slightly.

- Amargosa Desert. While water demand would decrease the availability of water in this downgradient area, the combined peak annual demand for the Proposed Action and the Nevada Test Site would be only about 4 percent of the average annual water pumped in the Amargosa Desert from 2000 to 2004, and an even smaller fraction of the estimated perennial yield for the Amargosa Desert. In recent years, groundwater in the Amargosa Desert has been over-appropriated compared to many estimates of perennial yield, but the amount actually withdrawn each year has averaged only about half of the total appropriations.

The Yucca Mountain FEIS described modeling that estimated how DOE's water demand would affect groundwater elevations and flow patterns. DOE's current projections of annual demand peaks for only 1 year at the long-term withdrawal rate assumed by those models, so their predicted results remain very conservative. Water demand for the Proposed Action and Nevada Test Site activities in Jackass Flats together would have, at most, small impacts on the availability of groundwater in the Amargosa Desert area compared with the quantities already being withdrawn there.

S.3.1.4 Biological Resources and Soils

S.3.1.4.1 *Biological Resources*

Biological resources include species that are typical of the Mojave and Great Basin deserts and generally common throughout those areas. DOE evaluated the potential for impacts to sensitive, threatened, or endangered species and their habitats. DOE also considered potential impacts to the migratory patterns and populations of game animals. Overall impacts would be small. The removal of vegetation from the area required for the repository and the small impacts to some wildlife species from disturbance or loss of individuals would not affect regional biodiversity and ecosystem function.

Impacts to vegetation from repository construction would occur as a result of direct disturbance. Repository-related activities have disturbed approximately 2.5 square kilometers (620 acres) and would disturb as much as 6.5 more square kilometers (1,600 acres). Construction could induce further colonization by invasive plant species already present, which could suppress native species and increase the fire-fuel load. However, because the vegetated area that would be disturbed is relatively small, and because DOE would reclaim areas no longer in use, impacts would be small.

Direct impacts to wildlife would occur through loss of habitat from construction; deaths of individuals of some species, particularly burrowing species of small mammals and reptiles, and deaths of individuals hit by vehicles; fragmentation of undisturbed habitat that created a barrier to wildlife movement; and displacement of wildlife because of noise and activity. Impacts would be small for many reasons. Habitats similar to those at Yucca Mountain are widespread locally and regionally. The animal species of concern are generally widespread in the region, and the impact of individual deaths on regional populations or biodiversity would be small. Large areas of undisturbed and unfragmented habitat would remain available. Impacts from noise and vibration would decline with distance, and some species would acclimate to the noise. No species would be threatened with extinction locally or regionally.

The Mojave population of the desert tortoise is listed as threatened under the *Endangered Species Act*. Construction would result in the loss of a small portion of tortoise habitat in an area where tortoise density is already low. DOE has had success relocating tortoises and their nests to safer terrain. Based on past experience, DOE estimates that the number of tortoises killed by vehicles and construction would be small and would not affect the species' long-term survival locally or regionally. As required by the *Endangered Species Act*, DOE has consulted with the U.S. Fish and Wildlife Service to ensure that the project's effects on the desert tortoise are minimized. This consultation would continue.

S.3.1.4.2 *Soils*

During construction, disturbing the land would make soil more susceptible to wind and water erosion. Because natural succession is slow on disturbed dry, semiarid lands, recovery would require reclamation. Continuing its current reclamation program, DOE would stockpile for use in reclamation the topsoil it removed during excavation. It would use fugitive dust control measures to protect the stockpile from wind erosion. Minimizing the extent of areas disturbed and using engineering practices to stabilize them would minimize erosion. During closure, DOE would revegetate as practicable areas it had not already reclaimed to reduce the loss of the most critical types of topsoil. Based on past experience DOE expects little erosion during any project phase.

Spills or releases of contaminants could occur, but DOE's continued implementation of its *Spill Prevention, Control, and Countermeasures Plan for Site Activities* would prevent, control, and remediate soil contamination. DOE would train workers to manage hazardous materials. Fueling operations and storage of hazardous materials and other chemicals would take place in bermed areas away from floodplains.

S.3.1.5 Cultural Resources

Cultural resources are nonrenewable, and the values they represent could be diminished by physical disturbance. This Repository SEIS evaluates the potential for damage or modification to the character of archaeological and historic sites and other cultural resources, with particular emphasis on those important to sustaining and preserving American Indian cultures. Overall, impacts to cultural resources would be small.

Direct impacts could result from ground disturbances and activities that would destroy or modify the integrity of archaeological or cultural resource sites. Indirect impacts could result from activities that increased the potential for intentional or unintentional adverse impacts, for example, illicit collection or inadvertent destruction. Although some indirect impacts could occur, the repository project's overall long-term effect would be beneficial because limits on access to and uses of the analyzed land withdrawal area would protect cultural resources from most human intrusion.

Because DOE would strive to avoid archaeological resources and would mitigate impacts to them, direct adverse impacts would be small. While easier physical access to the land withdrawal area could result in unauthorized excavation and collection of artifacts, DOE would mitigate such indirect impacts by training workers, monitoring archaeological sites, and establishing long-term management of the sites.

DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Officer have prepared a programmatic agreement to manage cultural resources during characterization of the Yucca Mountain site. The agreement is undergoing revision as part of negotiations with the State Historic Preservation Office. DOE will continue to work under the current agreement until a new one is in place.

S.3.1.5.1 *American Indian Viewpoint*

The Yucca Mountain FEIS summarized the American Indian view of resource management and preservation. Holistic in its concept of cultural resources, that view integrates elements of the natural and physical environment into a unified value system. To enhance the protection of archaeological sites and cultural items important to American Indians, DOE would maintain its commitment to its Native American Interaction Program throughout the implementation of the Proposed Action.

Because American Indians regard Yucca Mountain as integral to a valued cultural landscape, they consider the repository program to be intrusive and to constitute an adverse impact. Meetings with the Consolidated Group of Tribes and Organizations held since the completion of the Yucca Mountain FEIS indicate that this viewpoint has not changed.

S.3.1.6 Socioeconomics

DOE evaluated how the Proposed Action could affect employment, population, economic measures (real personal disposable income, spending by state and local governments, and Gross Regional Product), housing, and some public services. The operations period would result in the highest impacts to employment, population, Gross Regional Product, real disposable income, and government spending.

DOE’s analysis of impacts on employment is inherently complex. For example, it must discriminate between new workers and those who are already part of the employment baseline, and between total employment and incremental additions, and it must make assumptions about how many workers will in-migrate to work at the repository and how many already reside locally. However, by any measure, impacts to employment in Clark and Nye counties from repository-related construction and operations would be small. The number of jobs created directly and indirectly would peak in 2021 in both counties at around 1,300, a 0.09-percent increase above the projected employment baseline for that year. Indirect jobs would result from project expenditures, such as procurement of goods and services, and personal expenditures by directly employed workers.

DOE used the Regional Economic Models, Inc. (REMI) model, *Policy Insight* and State of Nevada demographer data to project that regional population would grow steadily from about 2.48 million residents in 2012 to about 5.13 million in 2067. The peak year contribution due to project workers and their households, in 2035, would be about 2,280 people, or about 0.06 percent of the 3.63-million-person baseline. Based on historical data, DOE assumes that 80 percent of the construction and operations workforce would live in Clark County and 20 percent would live in Nye County.

The proposed repository would increase real personal disposable income, spending by state and local government, and Gross Regional Product by less than one-third of 1 percent over projected baselines, in 2006 dollars. Gross Regional Product would peak in 2034 because of consumption of goods and services due to construction. The estimated increase would be about $168 million or 0.08 percent of the baseline, with about $98.7 million spent in Clark County and $68.9 million in Nye County.

DOE analyzed potential impacts to housing only at the county level because demand at the community level is inherently hard to predict. The increase in population due to the repository would occur over a long period and the housing market could readily respond. Given the region's large housing inventory, baseline population growth would mask changes due to the repository. Impacts would be more pronounced in Nye County, particularly in Pahrump, where recent growth has been rapid and largely unanticipated and unmanaged, the housing stock is limited, and much of the infrastructure to support housing development is at capacity.

Impacts to services such as schools, police and fire protection, and medical services would be small because repository-related population changes would be a small fraction of population growth in the region. Because most in-migrating workers would probably live in the many communities of metropolitan Clark County, their demand for public services would be dispersed.

In southern Nye County, particularly Pahrump, public services are currently at capacity, and the county is medically underserved. Because population changes would occur steadily over a long period, the county would be able to meet increased demands on services as its revenue base grew. Pahrump's new hospital and the ample medical services in the metropolitan Las Vegas area would help meet the need for medical services.

S.3.1.7 Health and Safety of Workers and the Public

The design of the repository is based on multiple safety principles and on proven nuclear industry precedent. Facility components are designed with robust margins, and they employ diverse and redundant systems. Mechanical handling, shielding, and related safety equipment are based on proven technology. The safety philosophy is based on design approaches and features for the prevention of events rather than consequence mitigation or administrative controls, on passive features rather than active features, and on automatic initiation rather than manual initiation of control.

The results of the preclosure safety analyses confirm that the Yucca Mountain site characteristics combined with the repository design provide an inherently safe facility that meets the preclosure performance objectives with substantial margin.

DOE estimated health and safety impacts to workers and to members of the public for each repository analytical period.

S.3.1.7.1 *Nonradiological Impacts*

Impacts to workers could include those from common industrial hazards, naturally occurring nonradioactive airborne hazardous materials, and unexploded ordnance. To estimate the impacts of industrial hazards for this Repository SEIS, DOE used the methods and data source it had used in the Yucca Mountain FEIS. The data source is the DOE Computerized Accident/Incident Reporting System (CAIRS). A compilation of data from DOE and DOE contractor operations, CAIRS contains annual numbers of total recordable cases and lost workday cases and the incidence rates per 100 full-time equivalent worker years. It also contains the annual number of total fatalities, which is used to calculate the fatality incident rate per 100,000 worker years. DOE applied these incident rates to estimate impacts to repository workers from industrial hazards.

Throughout the project, workers and the public could be exposed to naturally occurring cristobalite, a form of silica in rock that as dust causes silicosis and might be carcinogenic, and erionite, an uncommon zeolite mineral that forms wool-like fibrous masses and can be inhaled as dust. This Repository SEIS estimated that public exposures to cristobalite and public and worker exposures to erionite would be very small.

The project would last 105 years. DOE calculated total impacts to workers from industrial hazards for the entire project. For all workers, this SEIS estimated 1,800 total recordable cases, 800 lost workday cases, and less than 1 fatality.

S.3.1.7.2 *Radiological Impacts*

Since it completed the Yucca Mountain FEIS, DOE has modified its analysis of radiological impacts. The primary modifications include:

- Population distribution data. DOE now assumes operations would start in 2017 and last for as many as 50 years, so its analysis uses population projections updated to 2067. This is in contrast to the FEIS projection of population to the year 2035.

- Updated latent cancer fatality conversion factors. Measures of latent cancer fatality express the risk that a given dose of radiation would produce an additional cancer in an exposed population. To reflect current DOE guidance for converting worker and public doses to health effects, DOE used a conversion factor of 0.0006 latent cancer fatality per person-rem. The Yucca Mountain FEIS used two different LCF conversion factors: for workers, 0.0004 per person-rem, and for the public, 0.0005 per person-rem. This would result in a 50-percent and 20-percent impact increase from the FEIS for workers and the public, respectively, for the same radiation dose.

Construction of subsurface facilities would begin at the same time as construction of surface facilities. Disturbance of rock would result in releases of naturally occurring radon-222 and its decay products, which subsurface exhaust ventilation would pump to the surface. Throughout the project, workers and members of the public would be exposed to these releases. They could also be exposed to releases from radioactive materials at the site.

In the analysis of radiological impacts, this Repository SEIS calculates an annual dose to an individual or to a population and converts these doses to probabilities of latent cancer fatalities to express potential health effects. The impact for maximally exposed individuals is measured by the increase in the probability of a latent cancer fatality. For exposed populations, it is the estimated number of latent cancer fatalities that would result from the collective doses.

POPULATION DOSE AND FUTURE POPULATION SIZE

Population dose is a summation of the doses received by individuals in an exposed population (the unit of measure is *person-rem*). The population dose depends on the number of people at a given location. If the number increases, the population dose estimate does, too. The individual dose remains the same.

For workers, DOE estimated doses for maximally exposed involved workers and worker populations. About 80 percent of the doses to workers would occur during operations, principally from surface handling of spent nuclear fuel and subsurface monitoring and maintenance activities. The maximally exposed worker would be a cask operator who handled spent nuclear fuel at the surface and whose entire working lifetime spanned up to the 50-year operations period (an unlikely, and therefore conservative, assumption). The dose to that worker over a 50-year period would be about 30 rem, with an increase in latent cancer fatality risk of about 0.02. The total number of latent cancer fatalities for workers over the course of 105 years (project lifetime) would be about 4. DOE expects that workers would receive a dose much below that estimated in this repository SEIS, in keeping with DOE's safety goals and practices and experience with similar activities at existing DOE facilities.

For the public, DOE estimated impacts to the maximally exposed individual who would reside continuously for 70 years at the site boundary in the prevailing downwind direction. About 99.9 percent of the impact would be from exposure to airborne radon-222 and its decay products. The increase in probability of a latent cancer fatality during the preclosure period would be about 3 in 10,000. The highest annual dose would be 6.8 millirem, less than 4 percent of the annual average 200-millirem dose to members of the public from ambient levels of radon-222 and its decay products.

Over 105 years, the collective dose for the population within 80 kilometers (50 miles) would be 13,000 person-rem. This dose can be compared to 2.5 million person-rem the same population would receive from ambient levels of naturally occurring radon-222 and its decay products. The estimated health effects from this additional exposure to radioactivity would be 8 latent cancer fatalities.

S.3.1.8 Accidents and Sabotage Events

S.3.1.8.1 *Accidents*

DOE estimated impacts from reasonably foreseeable accidents for (1) the maximally exposed individual (an individual at the analyzed land withdrawal boundary who would receive the largest radiation dose from the accident), (2) the noninvolved worker (a worker 60 meters [200 ft] from the point of release from the accident), and (3) members of the public residing within 80 kilometers (50 miles) of the repository. Because waste handling operations would be performed remotely, involved workers would be in enclosed facility operating rooms isolated from the waste. Doses to the noninvolved worker could be as high as 2.3 rem. Impacts to offsite individuals from repository accidents would be small, with calculated doses of 23 millirem or less to the maximally exposed individual.

Since DOE completed the Yucca Mountain FEIS, it has acquired new information and analytical tools that contribute to the understanding of potential impacts of accidents. For this Repository SEIS, DOE has applied them to the evaluation of the accident scenarios.

With the current repository design and operational plans as its starting points, DOE considered external and internal events that could initiate accidents. External events would originate outside the repository and affect its ability to confine radioactive material; they include human-caused events such as aircraft crashes, external fires, and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal events would originate in the repository and would include human errors, equipment failures, or combinations of these.

DOE defined various accident scenarios that entail drops and collisions involving shipping casks, TAD canisters, dual-purpose canisters, uncanistered fuel assemblies, and a fire involving low-level waste drums. The analysis presents consequences for average and unfavorable meteorological conditions (which would be exceeded less than 5 percent of the time).

The maximum reasonably foreseeable accident scenario that would result in the highest offsite population impact involves the drop and breach of a dual-purpose canister containing 36 pressurized water reactor spent nuclear fuel assemblies. The maximum reasonably foreseeable accident scenario that results in the highest worker impact involves a seismic event that releases radioactive material from the high-efficiency-particulate-air filtration system and the Low Level Radioactive Waste Facility. Potential impacts under these accident scenarios to the offsite exposed population would be less than 1 additional latent cancer fatality (0.16) in a population of approximately 104,000 in the south-southeast direction within an 80-kilometer (50 mile) radius of the site. The seismic event could result in the highest dose and health impacts to workers, 2.3 rem, which could result in an increased latent cancer risk of 0.0014.

S.3.1.8.2 *Sabotage Events*

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the United States Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements intended to prevent terrorists from gaining control of commercial aircraft.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and intentional human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (before closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

NRC regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides “high assurance that activities involving spent nuclear fuel and high-level radioactive waste do not constitute an unreasonable risk to public health and safety.” The regulations require the storage of spent nuclear fuel and high-level radioactive waste in a protected area such that:

- Access to the material would require passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, to be continually monitored, and to be protected by an active alarm system.

- Adequate illumination must be provided for observation and threat assessment.

- The area must be monitored by random patrol.

- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

Although it is difficult to predict if sabotage events would occur, and the nature of such events if they were to occur, in response to public comments and to evaluate a scenario that would approximate the consequences of a major sabotage event, DOE analyzed a hypothetical scenario in which a large commercial jet aircraft would crash into and penetrate the repository facility with the largest inventory of radioactive material vulnerable to damage from such an event.

The analysis conservatively modeled that the aircraft impact would compromise the confining capability of the building and the resulting fire would convert 42 spent nuclear fuel assemblies to an oxide powder. The results of this analysis indicate that the maximally exposed offsite individual could receive a dose of 4.0 rem resulting in an estimated likelihood of a latent cancer fatality of 0.0024, and the offsite public in the highest population sector (south-southeast), which in 2067 would consist of an estimated 104,000 individuals, could receive a collective dose of 13,000 person-rem for average weather conditions resulting in an estimated 7.8 latent cancer fatalities.

S.3.1.9 Noise

The region of influence for noise includes the Yucca Mountain site and existing and future residences south of the analyzed land withdrawal area. Sources of noise during construction would be heavy equipment, ventilation fans, and diesel generators. Sources during operations and monitoring would include diesel generators, cooling towers, ventilation fans, air conditioners, and concrete batch plant activities. Ventilation fans would have suppressors to maintain noise levels below 85 dBA. The National Institute for Occupational Safety and Health and the American Conference of Governmental Industrial Hygienists both recommend an exposure limit of 85 dBA for an 8-hour exposure. Because the distance between repository noise sources and an individual at the boundary of the analyzed land withdrawal area would be great enough to reduce noise to background levels or below, and because there would be no residential or community receptors at the boundary, DOE expects no noise impacts to the public.

At times, workers at the repository site would be exposed to elevated levels of noise. DOE would use engineering controls to control noise levels and worker exposures, so impacts such as hearing loss would be unlikely. Workers would use personal hearing protection as necessary.

Sources of offsite noise would include construction of the access road from U.S. Highway 95 and facilities south of the Yucca Mountain site near Gate 510. Typical construction equipment would intermittently generate noise levels of about 85 dBA at 15 meters (50 feet). Because of the distance between construction activities and potential receptors and the temporary and intermittent nature of construction noise, DOE would not expect noise impacts to the public. Traffic on the access road would not significantly add to existing noise on U.S. Highway 95. Noise from offsite facilities would be typical of commercial environments and would not cause impacts.

S.3.1.10 Aesthetics

DOE’s analysis of aesthetic impacts considered the natural and manmade physical features that give a particular landscape its character and value, specifically scenic quality, visual sensitivity, and distance from observation points.

From publicly accessible locations, Yucca Mountain's visibility is limited. DOE identified two general locations from which the public could see repository facilities. One is approximately 22 kilometers (14 miles) to the south of the repository, near the intersection of Nevada State Route 373 and U.S. Highway 95. The other is west of the repository. From the latter location, repository ventilation exhaust stacks could be visible.

The low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south, and therefore the repository would cause a weak degree of contrast with the landscape. Exhaust ventilation stacks on the crest of Yucca Mountain would cause a moderate degree of contrast, and American Indians would consider the presence of the stacks an adverse aesthetic impact. Because of the height of the stacks, the U.S. Air Force might require DOE to install flashing beacon lights on top of them. Such beacons could be visible for several miles, especially to the west of Yucca Mountain, but would not be visible from Death Valley National Park.

Construction of the access road from U.S. Highway 95 and of offsite facilities near Gate 510 would be sources of short-term visual impacts. DOE would reclaim disturbed areas when they were no longer needed. Best management practices would ensure that construction created only a weak degree of contrast. When construction was complete, the access road and offsite facilities would cause a weak degree of contrast.

Closure activities, such as dismantling of facilities and site reclamation, would reduce the repository's visual contrast with the landscape.

S.3.1.11 Utilities, Energy, Materials, and Site Services

DOE calculated its needs for electricity, fossil fuel, oil, lubricants, construction materials, and services such as emergency medical support, fire protection, and security and law enforcement, and compared them with available supplies and capacity.

In general, quantities of utilities, energy, and materials the project used would be small in comparison to the regional supply capacity and would be unlikely to affect regional supplies or prices. A major reason is that the repository schedule would extend over decades.

As its repository program proceeds, DOE would examine how it could modify its engineering, construction, and operational plans to take advantage of emerging green technologies, in order to reduce its consumption of nonrenewable resources, including fossil fuels.

S.3.1.12 Repository-Generated Waste and Hazardous Materials

Repository construction, operations, monitoring, and closure would generate waste and entail the use of hazardous materials. DOE identified types of waste and hazardous materials and estimated the maximum quantities it would generate for each project period. The types include construction and demolition debris, industrial wastewater, low-level radioactive waste, sanitary sewage, sanitary and industrial waste, hazardous waste, mixed waste, and transuranic waste. DOE could build onsite solid waste facilities to accommodate nonhazardous waste or dispose of such waste at offsite facilities. DOE would manage industrial wastewater with onsite evaporation ponds.

DOE would dispose of construction and demolition debris and sanitary and industrial waste either at an onsite landfill or at offsite facilities. Hazardous waste and low-level radioactive waste would be disposed of in offsite facilities. The impact on offsite disposal facilities of the amounts of waste generated during all project periods would be small because current capacities could readily accommodate estimated quantities. Best management practices would reduce the amount of waste generated.

S.3.1.13 Environmental Justice

As in the Yucca Mountain FEIS, in this Repository SEIS DOE does not identify any high and adverse potential impacts to populations. Further DOE has not identified subsections of the population, including minority or low-income populations, that would receive disproportionate impacts, and it has identified no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income populations to disproportionately high and adverse impacts. Therefore, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

In the Yucca Mountain FEIS, DOE acknowledged that members of American Indian tribes have used lands around the Yucca Mountain site that contain cultural, animal, and plant resources important to them. The FEIS presented views and beliefs about those lands that tribal members had expressed. DOE continues to recognize that the Proposed Action would conflict with the viewpoint expressed by the American Indian Writers Subgroup in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement*.

S.3.2 POTENTIAL POSTCLOSURE IMPACTS OF THE REPOSITORY

S.3.2.1 Analytical Framework and Tools for Assessment

S.3.2.1.1 *The Regulatory Framework*

In 2001, both EPA and NRC adopted public health and safety standards for radioactive materials disposed of in the Yucca Mountain repository based on a dose not to be exceeded for the "reasonably maximally exposed individual" (RMEI) during the first 10,000 years. In 2004, in response to legal challenges, the U.S. Court of Appeals for the District of Columbia Circuit struck down the portions of those standards that addressed the period of time for which compliance must be demonstrated, and it remanded the provisions to the federal agencies for revision.

WHO AND WHERE IS THE "RMEI"?

A hypothetical "reasonably maximally exposed individual (RMEI)" is defined for the purpose of assessing potential doses that could result from releases of radioactivity from a repository.

Under applicable regulations, the RMEI is located 18 kilometers (11 miles) from the repository.

In 2005, EPA proposed new standards to address the court's decision. The proposed EPA standards incorporate multiple compliance criteria applicable at different times for protection of individuals and the environment, and in circumstances involving human intrusion into the repository. Because the *Energy Policy Act of 1992* requires NRC to modify its technical requirements for licensing of the Yucca Mountain repository to be consistent with the standards promulgated by EPA, NRC also proposed new standards in 2005 to implement the proposed EPA standards.

To obtain NRC authorization to construct the Yucca Mountain repository, DOE must demonstrate that the proposed repository meets the regulatory individual radiation protection standards set by EPA and NRC. Under the existing standards, estimated repository performance will be compared to a mean annual dose of 15 millirem for the first 10,000 years after closure. Under the proposed standards, estimated repository performance will be compared to a median annual dose of 350 millirem for the post-10,000-year period. In this Repository SEIS, comparison to the existing and proposed standards is intended only to provide a perspective on potential health impacts.

WHY 10,000 YEARS AND 1 MILLION YEARS?

The TSPA-SEIS model provides estimates of potential radiological impacts (doses) for two periods: the estimated dose at times up to 10,000 years after closure and a dose at times after 10,000 years and up to 1 million years after closure. The TSPA-SEIS model assessed annual individual doses in each of these periods.

DOE could have performed the analyses for this Repository SEIS for any number of periods. So why these two? The main reason is that EPA and NRC have existing and proposed dose limits for the annual individual dose in each period. While these dose limits will provide a regulatory limit against which NRC could evaluate DOE's application for construction authorization, they also provide a context in which to consider the potential environmental impacts of the Proposed Action.

S.3.2.1.2 *Estimating Repository Performance in the Postclosure Period*

DOE estimates postclosure repository performance by means of probabilistic modeling in computer simulations using numerical data. The model that DOE has developed to estimate repository performance after closure is called the Total System Performance Assessment (TSPA). The version of the model used to represent the results in this Repository SEIS is called the TSPA-SEIS. The TSPA-SEIS reflects modifications made to repository design since the Yucca Mountain FEIS was completed. It also reflects the acquisition of more scientific data and the refinement of models, which serve to further reduce levels of uncertainty associated with assessments of repository performance.

The results of assessments of postclosure repository performance for this Repository SEIS and those of the Yucca Mountain FEIS are different. The differences are due to the use in this Repository SEIS of a TSPA model that is consistent with newly proposed EPA standards, as well as to the incorporation of additional data and enhancements in the description of engineered and natural components. In addition, the TSPAs for the Yucca Mountain FEIS and the Repository SEIS use different representations for earthquakes, climate change, and volcanism. As a result of these differences, several qualitative observations can be made about the FEIS results.

- The FEIS described future climates in terms of discrete alternating climate states with a precise timing of climate change. The spikes in the dose curves shown in the FEIS (for example, FEIS, page 5-26, Figure 5.4) result from imposed climate changes at fixed times and assumed percolation fluxes. These spikes are responsible for the maximum levels of the individual dose. The proposed EPA standards require DOE to represent long-term climate using a probabilistic distribution for a constant-in-time but uncertain long-term average climate for Yucca Mountain specified by NRC. Inclusion of these changes in the FEIS would have resulted in a significant lowering of the projected dose values.

COMPARISON OF DOSES IN THE YUCCA MOUNTAIN FEIS AND IN THE REPOSITORY SEIS

For the post-10,000-year period, the maximum mean annual individual dose reported in the Yucca Mountain FEIS is 154 millirem per year, while the maximum mean annual individual dose reported in the Repository SEIS is 2.3 millirem per year. Any comparison of these two numbers must take into account the differences in the modeling that resulted in the two results. Specifically, the modeling for the Repository SEIS reflects regulatory direction in the EPA proposed standards on how to treat certain features (e.g., climate) and also reflects DOE's current assessment as to what are the appropriate assumptions to use in demonstrating compliance under a reasonable expectation standard. DOE expects that the maximum annual individual dose in the final Repository SEIS to be submitted to NRC in connection with DOE's submission of the application for construction authorization will not be substantially different from the maximum annual individual dose reported in this draft Repository SEIS. It should be noted, however, that various elements of our modeling approach may be challenged as part of the NRC licensing process. Depending on the outcome of any such challenges, the maximum annual individual dose ultimately considered by NRC in making its decision whether to authorize construction may be higher or lower than the maximum annual individual doses reported in the Yucca Mountain FEIS or the Repository SEIS.

- The proposed EPA standards require DOE to use revised International Commission on Radiation Protection weighting factors for calculation of individual doses. In general, biosphere dose conversion factors for actinides are lower, whereas biosphere dose conversion factors for fission products are higher. Actinides were the dominant contributors to dose in the FEIS. Notably, the biosphere dose conversion factors for neptunium, which was the dominant nuclide contributing to doses in the FEIS, decreased by approximately 80 percent from the FEIS to the SEIS with the Commission's revisions. Sensitivity studies referenced in the FEIS (FEIS page 5-31) indicate that dose estimates would be significantly lower if the revised Commission methods were applied.

- Waste package and drip shield lifetimes are longer in the SEIS. The increase in waste package lifetimes is due in part to the increase in thickness of the Alloy 22 outer barrier to accommodate the TAD canister. Inclusion of temperature dependence of Alloy 22 corrosion rates in the SEIS results in substantially longer waste package lifetimes in the Nominal Scenario Class. Inclusion of new titanium corrosion data in the SEIS resulted in lower corrosion rates, reduced uncertainty, and longer drip shield lifetimes. Inclusion of these enhanced models in the FEIS would have resulted in a significant lowering of the projected dose values.

DOE has made other refinements to the TSPA model for the SEIS to improve the treatment of uncertainties, incorporate new data and understanding of processes, and reduce conservatism in the projection of repository performance.

S.3.2.1.3 *The Focus of Analyses*

In this Repository SEIS, DOE's analysis examines impacts on human health from radioactive and nonradioactive materials (hazardous and carcinogenic chemicals in the engineered barriers) released to the environment, biological and environmental impacts from radiological and chemical groundwater contamination, and biological impacts from heat due to decay of radioactive materials. It examines three transport pathways through which releases could reach human populations: groundwater, surface water, and the atmosphere.

Radioactive releases and groundwater are of primary concern. Groundwater is of concern because rainwater could migrate into the repository, dissolving or mobilizing material in it and carrying contaminants down through the groundwater system into an aquifer (Figures S-3 and S-11). Through a well or at a surface-water discharge point, humans would draw that water for use as drinking water or for irrigation and watering livestock, through which it could enter the human food chain.

The TSPA-SEIS evaluates radiological impacts over two time frames: the first 10,000 years and up to one million years after repository closure. The end point is an estimate of an annual dose to an individual, expressed in millirem. Converting doses to the probability of latent cancer fatalities provides an estimate of health effects.

The Repository SEIS examines the annual dose to the RMEI at a location 18 kilometers (11 miles) south of Yucca Mountain in the direction of groundwater flow. The RMEI is a hypothetical individual who lives above the highest concentration of radionuclides in the plume of radioactive contamination, and drinks 2 liters of water per day from wells drilled into the groundwater at that location. DOE estimated the annual RMEI dose and groundwater impacts using a representative volume of 3000 acre-feet of groundwater, consistent with the regulatory requirements applicable to projections of repository performance for Yucca Mountain to calculate the concentration of radionuclides. The TSPA-SEIS model collected the radionuclides released at a given time and used that number to project the concentration of radionuclides released from the Yucca Mountain disposal system into the representative volume. That concentration of radionuclides is used to determine the annual dose to the RMEI, which is expressed in millirem.

S.3.2.1.4 *The Nature of Analyses*

For the Repository SEIS, DOE performed 300 model simulations using TSPA for the RMEI location. Analyses examine the possible effects of "scenario classes" that include such expected processes as corrosion and degradation of waste packages and drip shields, degradation and dissolution of waste forms, flow through the saturated and unsaturated zones, and changing climate. They also consider early waste package and drip shield failure mechanisms, igneous and seismic events, and such disturbances as exploratory drilling and criticality.

The analysis draws from comprehensive data on engineered barriers and studies of the natural features of the site. But many parameters about the latter cannot be exactly quantified or known, and of course the more complex and variable a system is and the further into the future a forecast extends, the greater the level of uncertainty. DOE uses a variety of analytic techniques to gauge how sensitive end results are to uncertainties and data limitations, and thus how much they matter. Where assumptions must be made, they are generally conservative. DOE also draws upon expert opinion. Its analysis explicitly accounts for uncertainty and expresses results as ranges of potential consequences.

The goal is a cautious but reasonable projection of what might occur. The Repository SEIS explains sources of uncertainty and how DOE handles it in modeling. Continued testing and monitoring at the Yucca Mountain site and analysis of findings in the future will further reduce uncertainty.

S.3.2.2 Postclosure Radiological Impacts

The safe long-term isolation of nuclear waste in the Yucca Mountain repository would result from the performance of multiple natural and engineered features of the site and the system, acting in concert, to prevent or delay the transport of radioactive materials to points at which the public could eventually be exposed to them. Each of the barriers in the system would work individually and together to limit the movement of water and the release and movement of radionuclides. Yucca Mountain's geologic and hydrologic characteristics form effective natural barriers to the flow of water and to the potential movement of radionuclides. The underground environment within the natural setting is conducive to the design and construction of components that would prevent or reduce the movement of water or the potential release and transport of radionuclides. The Engineered Barrier System consists of components designed to function in the natural environment of the unsaturated rock units, and it uses materials chosen to perform their intended functions for many thousands of years. Analyses indicate that a Yucca Mountain repository could be expected to effectively isolate waste for tens of thousands to hundreds of thousands of years.

The Yucca Mountain site was selected, and the repository designed, to take advantage of the attributes of the natural setting at Yucca Mountain. Because water is the primary medium by which radionuclides could be released from the repository, the beneficial characteristics of the repository primarily relate to the ability of the site and the design to limit the movement of water into and out of repository emplacement drifts. The attributes of the disposal system that are particularly important to post-closure performance include an unsaturated zone and facility design that will limit water entering emplacement drifts, long-lived drip shields and waste packages that will prevent or limit the contact of water and waste, other engineered features that will contribute to limiting radionuclide release, natural features that will delay and reduce the concentration of radionuclides, and a disposal system concept that results in low mean annual radiological doses even when potentially disruptive events are considered.

The performance analysis for the first 10,000 years after closure indicates that there would be very limited combined releases with small radiological impacts for the total of all scenario classes. For the first 10,000 years after repository closure, the mean annual individual dose would be approximately 0.24 *millirem*. This is about 1 percent of the existing EPA standard, which allows up to a 15-millirem annual committed effective dose equivalent during the first 10,000 years.

CALCULATION OF MEAN, MEDIAN, AND 95TH-PERCENTILE RESULTS

Because of the probabilistic nature of the TSPA results, it is informative to examine the mean and median results, which are measures of central tendencies or average values, and the 95th percentiles, which represent the high extreme values.

Analyses indicate that for the post-10,000-year period, the median annual individual doses would be approximately 0.98, respectively. The median value is about 0.2 percent of the proposed EPA standard, which allows up to a 350-millirem annual committed effective dose equivalent for the post-10,000-year period. In addition, the mean and 95th-percentile values are well below the proposed EPA standard (Figures S-12 and S-13).

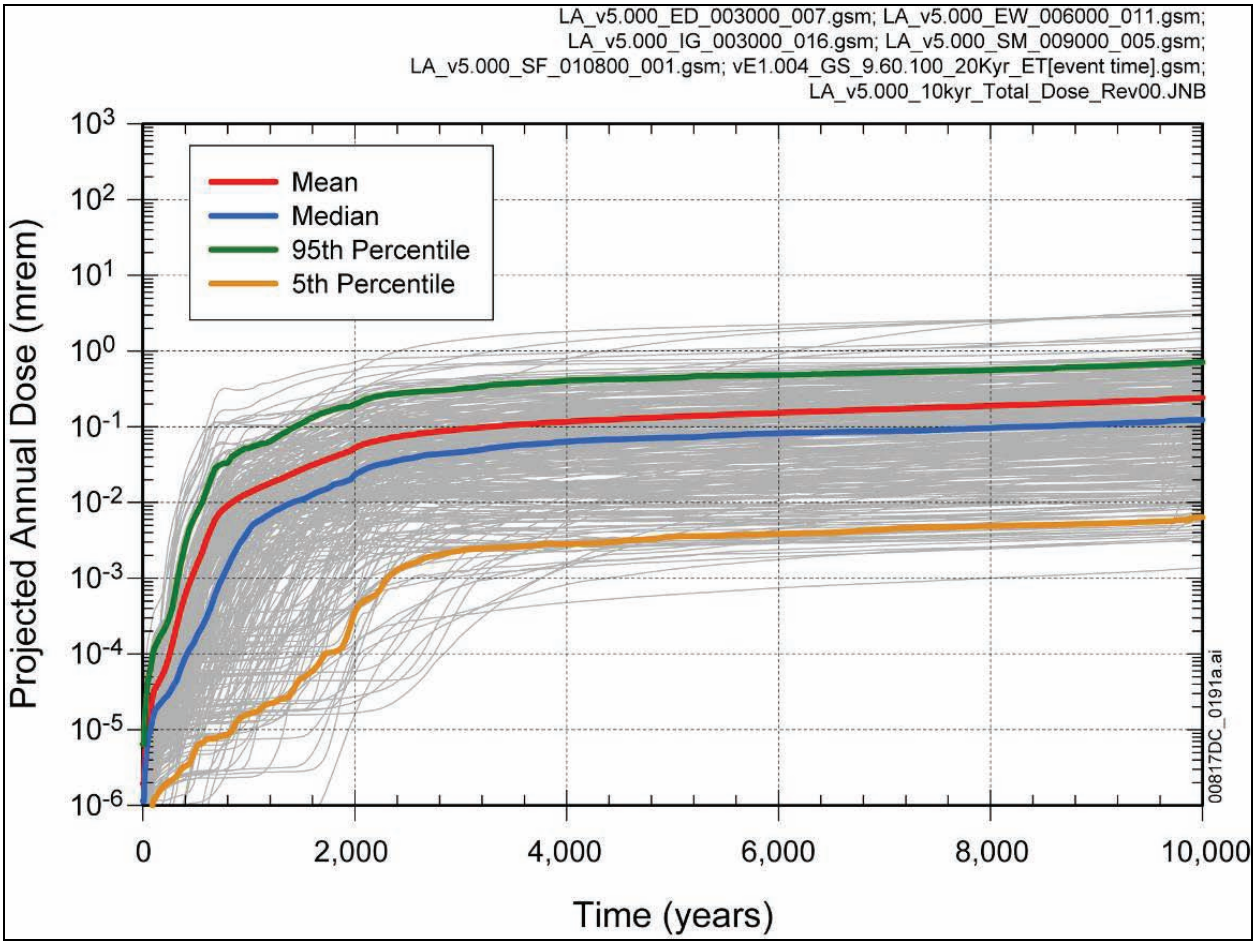


Figure S-12. Projected total annual dose for the first 10,000 years after repository closure–combined drip shield early failure, waste package early failure, igneous intrusion, volcanic eruption, seismic ground motion, and seismic fault displacement modeling cases.

S.3.2.2.1 *Human Intrusion*

A human intrusion scenario, in which a driller would penetrate a waste package without realizing it, is difficult to envision because of the design of the drip shields and waste packages. It is more plausible that the engineered barriers would deflect or divert a borehole that penetrated the repository. It is also more plausible that the drillers would recognize the intrusion. Nonetheless, DOE adopted a simple conservative calculation method to estimate the earliest time at which a drilling intrusion could occur, based on the fact that the waste package would be susceptible to drilling once the drip shield failed. DOE conservatively assumed that waste package failure and inadvertent drilling would occur at the same time. Based on this analysis, the earliest time that this could happen is estimated to be 200,000 years after closure.

DOE conducted a TSPA calculation for the drilling intrusion scenario for all environmental pathways to represent the dose from a single waste package. The mean and median annual individual doses from human intrusion would both be less than 0.01 millirem and would occur approximately 4,000 years after intrusion. These results indicate that the repository would be sufficiently robust to limit releases from

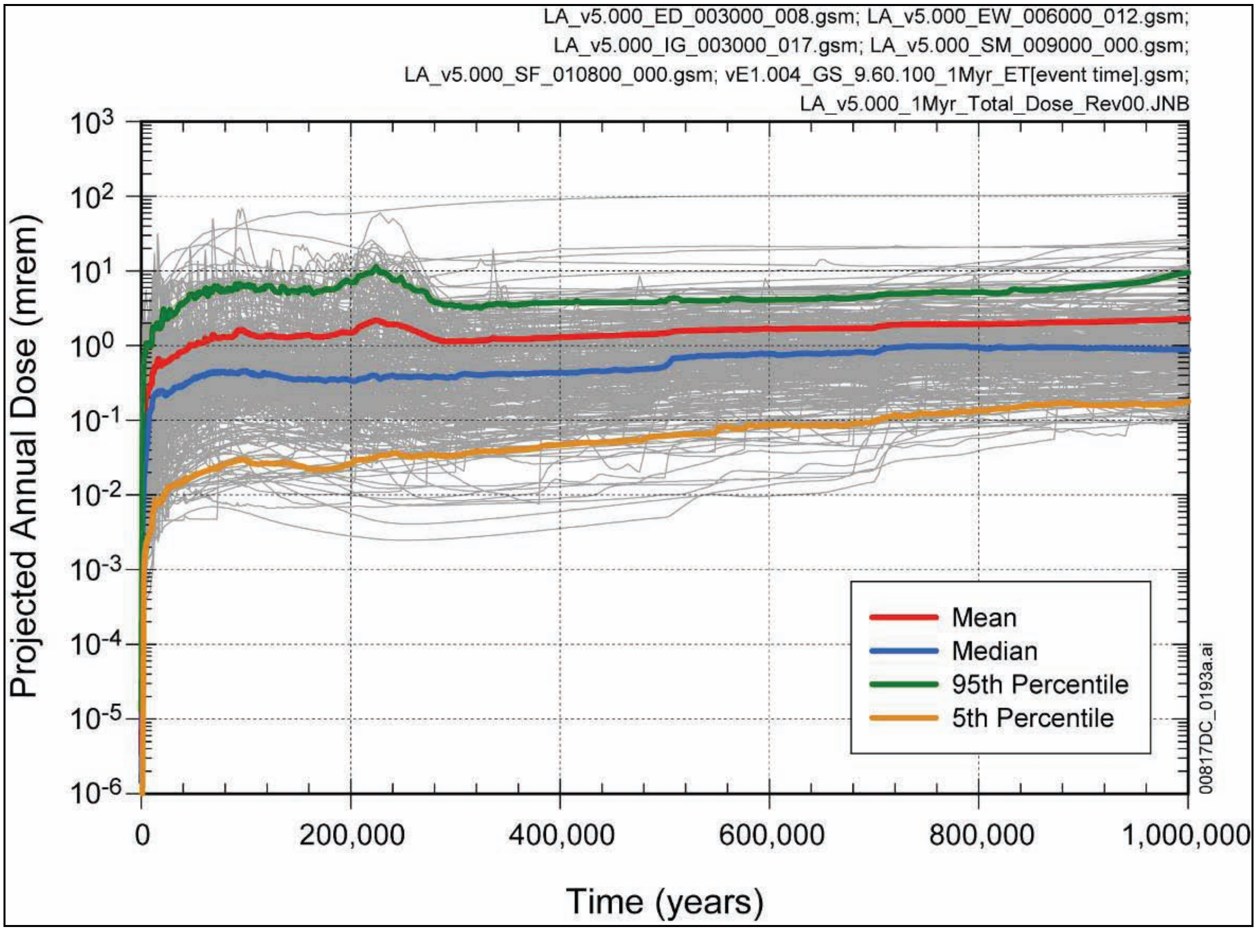


Figure S-13. Projected total annual dose for the post-10,000-year period–combined drip shield early failure, waste package early failure, igneous intrusion, volcanic eruption, seismic ground motion, and seismic fault displacement modeling cases.

human intrusion to values well below the proposed individual protection standard of 350-millirem annual individual dose for human intrusion for intrusions in the post-10,000-year period.

S.3.3 TRANSPORTATION IMPACTS

After DOE completed the Yucca Mountain FEIS in 2002, it issued a Record of Decision that selected the mostly rail scenario for the transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. Since completing the Yucca Mountain FEIS, DOE has continued to develop the repository design and associated operational plans. The Department now plans to operate the repository with the use of a primarily canistered approach that calls for the packaging of most commercial spent nuclear fuel at the commercial sites in TAD canisters and most DOE materials in disposable canisters at the DOE sites. There have also been changes to some of the data DOE used to estimate radiation doses and radiological impacts. Changes unique to the analysis of potential impacts from transportation are described below.

- 2000 Census population density data and updated rail and truck transportation networks. DOE used the TRAGIS computer program to determine representative transportation routes to the repository. The Department used 2000 Census data to estimate population densities along the routes. In the

FEIS, the TRAGIS program used 1990 Census data, which was escalated on a state-by-state basis to reflect the most current basis.

DOE evaluated the impacts of severe transportation accidents and sabotage events for an urban area. The Department based the population density in this urban area on the population densities in the 20 most populous urban areas using 2000 Census data.

- Shipment estimates. DOE has developed updated estimates of shipments that incorporate the use of TAD canisters at each commercial reactor site. The Department based shipment estimates on 90 percent (by MTHM) of the commercial spent nuclear fuel being shipped in rail casks that contained TAD canisters. Shipment of the remaining 10 percent of the commercial spent nuclear fuel would be in rail casks that contained other types of canisters such as dual-purpose canisters or as uncanistered spent nuclear fuel in truck casks.

  These new estimates project the shipment of approximately 9,500 rail casks and 2,700 truck casks of spent nuclear fuel and high-level radioactive waste to the repository. Shipping 9,500 rail casks would require about 2,800 trains. As identified in S.2.1.4, the FEIS analyses projected 9,600 rail cask shipments and 1,000 truck cask shipments.

- Radionuclide inventories. DOE has updated the radionuclide inventory for commercial spent nuclear fuel to incorporate the inventories from *Characteristics for the Representative Commercial Spent Nuclear Fuel Assembly for Preclosure Normal Operations*.

- Sabotage. DOE reanalyzed impacts from potential sabotage events using spent nuclear fuel release fraction data that were not available at the time the Yucca Mountain FEIS was prepared.

S.3.3.1 National Transportation Impacts

Shipments of spent nuclear fuel and high-level radioactive waste would represent a very small fraction of total national highway and railroad annual traffic (less than 0.1 percent).

The analysis of potential impacts associated with national transportation of spent nuclear fuel and high-level radioactive waste includes evaluation of incident-free impacts (normal operations), transportation risk (an assessment of potential accident consequences taking into account the probabilities of each accident), and the estimated consequences of a maximum reasonably foreseeable accident. The overall national transportation impacts include those that would be expected at the generator sites from loading TAD canisters and transportation casks and address projected exposures of workers and the public to both radiological and non-radiological hazards (traffic accidents and vehicle emissions).

For incident-free transportation, DOE estimated that about 4 latent cancer fatalities could occur in the population of transportation workers exposed to radiation from the shipments. Because many workers would be involved, the risk for an individual worker would be small. DOE estimated that there would be about 1 latent cancer fatality among members of the public who would be exposed to radiation. Because this estimate is for the entire population of individuals who would be exposed along the transportation routes over the course of shipments to the repository, the risk for a single individual would be small.

The estimated radiological accident risk of a single latent cancer fatality for the entire population within 80 kilometers (50 miles) of the rail and truck transportation routes would be about 0.0025 (1 chance in 400) during as many as 50 years of shipments to the repository. Because this risk is for the entire population of individuals along the transportation routes, the risk for any single individual would be small.

The estimated nonradiological impacts of accidents (traffic fatalities) would be 3 fatalities during as many as 50 years of shipments to the proposed repository.

The maximum reasonably foreseeable transportation accident analyzed in this Repository SEIS is estimated to occur with a frequency of about 8×10^{-6} per year. This accident would involve a long-duration, high-temperature fire that would engulf a rail cask. If the accident occurred in an urban area, DOE estimated that there would be 9 cancer fatalities in the exposed population. If the accident occurred in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.012 (1 chance in 80) in the exposed population.

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the United States Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements intended to prevent terrorists from gaining control of commercial aircraft and additional measures imposed on foreign passenger carriers and domestic and foreign cargo carriers, as well as charter aircraft.

The Federal Government has also greatly improved the sharing of intelligence information and the coordination of response actions among federal, state, and local agencies. DOE has been an active participant in these efforts. In addition to its domestic efforts, DOE is a member of the International Working Group on Sabotage for Transport and Storage Casks, which is investigating the consequences of sabotage events and exploring opportunities to enhance the physical protection of casks.

The Department, as required by the NWPA, would use NRC-certified shipping casks. Spent nuclear fuel is protected by the robust metal structure of the shipping cask, and by cladding that surrounds the fuel pellets in each fuel rod of an assembly. Further, the fuel is in a solid form, which would tend to reduce dispersion of radioactive particulates beyond the immediate vicinity of the cask, even if a sabotage event were to result in a breach of the multiple layers of protection.

In addition, the NRC has promulgated rules (10 CFR 73.37) and interim compensatory measures (67 FR 63167, October 10, 2002) specifically to protect the public from harm that could result from sabotage of spent nuclear fuel casks. The Department has committed to following these rules and measures (69 FR 18557, April 8, 2004).

For the reasons stated above, DOE believes that under general credible threat conditions the probability of a sabotage event that would result in a major radiological release would be low. Nevertheless, because of the uncertainty inherent in the assessment of the likelihood of a sabotage event, DOE has evaluated events in which a military jet or commercial airliner would crash into a spent nuclear fuel cask or a modern weapon (a high energy density device) would penetrate a spent nuclear fuel cask.

In the Yucca Mountain FEIS (Appendix J, Section J.3.3.1), DOE evaluated the ability of large aircraft parts to penetrate shipping casks and found that that neither the engines nor shafts would penetrate a cask and cause a release of radiological materials if an aircraft were to crash into a spent nuclear fuel cask.

In the Yucca Mountain FEIS, DOE estimated the potential consequences if a sabotage event in which a high energy density device penetrates a rail or truck cask. For this Repository SEIS, DOE obtained more recent estimates of the fraction of spent fuel materials that would be released (release fractions). Based on the more recent information, DOE estimated that there would be 28 latent cancer fatalities in the exposed population if the sabotage event occurred in an urban area. If the sabotage event took place in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.055 (1 chance in 20). For sabotage events involving penetration of a spent nuclear fuel rail cask with a high energy density device, DOE estimated that there would be 19 latent cancer fatalities in the exposed population if the sabotage event occurred in an urban area. If the sabotage event took place in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.029 (1 chance in 30).

The Department would continue to modify its approach to ensuring safe and secure shipments of spent nuclear fuel and high-level radioactive waste between now and the time of shipments.

S.3.3.2 Nevada Transportation Impacts

The Rail Alignment EIS analyzes the potential impacts of rail line construction and operation along common segments and alternative segments within the Caliente and Mina rail corridors for the purpose of determining an alignment for the construction and operation of a railroad for shipments of spent nuclear fuel, high-level radioactive waste, and other materials from an existing rail line in Nevada to a geologic repository at Yucca Mountain. The Rail Alignment EIS also analyzes the potential impacts of constructing and operating support facilities. The impacts of this proposal have been included in the summary tables presented in Section 9.1, Major Conclusions. Additional detail regarding the impacts of constructing and operating a railroad in Nevada can be found in the Rail Alignment EIS.

S.4 No-Action Alternative and Its Impacts

Under the No-Action Alternative, DOE would not construct a repository at Yucca Mountain. Consistent with Section 113(c)(3) of the NWPA, DOE would curtail work at the site and undertake site reclamation to mitigate any significant adverse environmental impacts.

This Repository SEIS summarizes, incorporates by reference, and updates the Yucca Mountain FEIS analysis of environmental impacts associated with the No-Action Alternative. To assess potential health and safety impacts, DOE has used updated radiation dose coefficients and an updated latent cancer fatality conversion factor.

For this Repository SEIS, DOE has reconsidered its evaluation of the No-Action Alternative analytical scenarios and has elaborated on the uncertainties, and therefore unpredictability, of future actions under them. It has also considered developments related to a potential private fuel storage facility in Utah.

The immediate impacts of the No-Action Alternative are straightforward. Decommissioning and reclamation of the Yucca Mountain site would begin as soon as practicable and could take several years to complete. DOE would remove or shut down surface and subsurface facilities and restore disturbed lands. Short-term impacts on resource areas would be small.

Beyond that timeframe, developments become speculative, because DOE cannot predict the future course that Congress and commercial utilities and other parties would take in the absence of a repository. The possibilities could include these:

- Continued storage of spent nuclear fuel and high-level radioactive waste at each generator site in expanded onsite storage facilities,
- Storage of these materials at one or more centralized locations,
- Study and selection of another site for a geologic repository,
- Development of new technologies, and
- Reconsideration of alternatives to geologic disposal.

Because the uncertainties and range of possibilities are so large, the Yucca Mountain FEIS focused its analysis on the potential impacts of two scenarios:

- No-Action Scenario 1. DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-ground dry storage facilities at four sites. Commercial utilities would continue to manage their spent fuel at current locations. All sites would remain under institutional control, which would ensure protection of workers and the public under current federal regulations. Storage facilities would undergo one major repair during the first 100 years and replacement every 100 years after that. Replacement facilities would be sited next to existing facilities.
- No-Action Scenario 2. For the first 100 years, this scenario would be identical with Scenario 1. The scenario assumes no institutional control beyond that time. After about 100 years and up to 10,000 years, storage facilities at all sites would begin to deteriorate, and they would eventually release radioactive materials to the environment.

This Repository SEIS estimates the potential impacts of the No-Action Alternative at commercial and DOE sites for both scenarios for the first 10,000 years and for periods up to a million years. Under Scenario 1, which assumes the existence of institutional controls, the estimated radiological health impacts to workers and the public for the first 10,000 years would be about 18 latent cancer fatalities. For Scenario 2, which assumes the lack of institutional controls after 100 years, the evaluation of the 10,000-year period in the Yucca Mountain FEIS found that the original storage facility and containment vessels would be compromised. Radionuclides would enter the accessible environment with, eventually, catastrophic consequences for human health. This SEIS estimates the radiological health impacts to the public during the 10,000-year period to be over 1,000 latent cancer fatalities.

For estimates of impacts up to 1 million years for Scenario 1, the integrated impacts over the million-year period would be approximately 100 times those of the estimated 10,000-year impacts. For Scenario 2, however, the projection of estimated impacts would be more speculative. Beyond 10,000 years, the unchecked deterioration and dissolution of the materials would continue and increase impacts even further than those estimated for the 10,000-year period. The increasing uncertainty (for example, actual locations of radiological materials, climate changes, and degree of institutional control) over this extended period, however, does not provide a meaningful basis for quantitative impact analyses because of the limitless number of scenarios that could occur.

S.5 Cumulative Impacts of the Proposed Action

For this Repository SEIS, DOE updated the Yucca Mountain FEIS evaluation of cumulative preclosure impacts from the construction, operation, monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative postclosure impacts after repository closure. DOE also updated the evaluation of cumulative impacts from transportation of spent nuclear fuel and high-level radioactive waste to the repository both nationally and within the state of Nevada. The SEIS analysis reflects the longer time period assumed for repository operations and transportation, DOE's decision to ship most waste by rail, and updated assumptions about waste inventories.

Cumulative Impacts

A cumulative impact is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions" (Council on Environmental Quality Regulations, 40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively potentially significant actions that occur over time.

DOE's assessment of the environment around the Yucca Mountain site took into account the cumulative impacts of past and present actions in the area the Proposed Action would affect. Reasonably foreseeable future actions include the disposal of inventories of spent nuclear fuel and high-level radioactive waste that exceed the Proposed Action inventory of 70,000 MTHM, along with activities at the Nevada Test and Training Range and Nevada Test Site, DOE waste management and transmission/distribution activities, and Nye County activities, including the implementation of the Gateway Area Concept Plan, designed to manage the development of land south of the analyzed land withdrawal area.

DOE is preparing the *Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership*. The Global Nuclear Energy Partnership (GNEP) would encourage expansion of domestic and international nuclear energy production while reducing nuclear proliferation risks, and reduce the volume, thermal output, and radiotoxicity of spent nuclear fuel before disposal in a geologic repository. DOE believes there would be no change in the spent nuclear fuel and high-level radioactive waste inventory analyzed under the Proposed Action of this Repository.

Overall, development of a GNEP fuel cycle has the potential to decrease the amount (number of assemblies) of spent nuclear fuel that would require geologic disposal, but could increase the number of canisters of high-level radioactive waste requiring geologic disposal in the longer term. Consequently, the proposed recycling of commercial spent nuclear fuel could affect the nature of the inventory that represents the balance of Inventory Module 1 (as discussed below). Nevertheless, given the uncertainties inherent at this time in estimating the amount of spent nuclear fuel and high-level radioactive waste that would result from full or partial implementation of GNEP, this Repository SEIS analyzes the transportation and disposal of about 130,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel and about 36,000 canisters of high-level radioactive waste (Inventory Module 1).

S.5.1 INVENTORY MODULES 1 AND 2

Section 114(d) of the NWPA provides that no more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste may be disposed of in a first repository until a second repository is operating. DOE evaluated the emplacement of the total projected inventory of commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste (Inventory Module 1) and emplacement of that total inventory plus the inventories of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste (also referred to by DOE as “Greater-Than-Class-C-like” waste (Inventory Module 2). This Repository SEIS updates the inventories of the modules evaluated in the Yucca Mountain FEIS.

INVENTORIES

Proposed Action

- 63,000 MTHM of commercial spent nuclear fuel and a very small quantity of commercial high-level waste
- 2,333 MTHM of DOE spent nuclear fuel
- 4,667 MTHM (9,334 canisters) of DOE high-level radioactive waste

Inventory Module 1

- 130,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 36,000 canisters of DOE high-level radioactive waste

Inventory Module 2

- 130,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 36,000 canisters of DOE high-level radioactive waste
- 2,000 cubic meters (70,000 cubic feet) of Greater-Than-Class-C waste
- 4,000 cubic meters (140,000 cubic feet) of Special-Performance-Assessment-Required waste (Greater-Than-Class-C-like low-level radioactive waste)

The emplacement of Inventory Module 1 or 2 at Yucca Mountain would require legislative action by Congress. The emplacement of commercial Greater-Than-Class-C and DOE Special-Performance-Assessment-Required wastes could require either legislative action or a determination by NRC to classify these materials as high-level radioactive waste.

The emplacement of Inventory Module 1 or 2 would increase the size of the subsurface repository facilities and, thus, the amount of land disturbed. Because over twice as much radiological materials would be handled during the emplacement of Inventory Module 1 or 2, these actions would produce greater health impacts to workers and the public, increase energy use, create larger amounts of waste, and increase transportation impacts. While impacts in all resource areas would still be low, the specific impacts to health and safety at the repository and from transportation are discussed below.

S.5.2 IMPACTS TO WORKERS AND THE PUBLIC

Impacts from industrial hazards. The total estimated impacts from industrial hazards for Inventory Module 1 or 2 would be 50 percent larger than those for the Proposed Action. The potential number of reportable injuries and illnesses could be about 2,700, and the estimated number of fatalities would be 1.2.

Radiological impacts to workers. Latent cancer fatalities for repository workers during the construction, operation, monitoring, and closure periods for Module 1 or 2 could be about 9 fatalities, about double that estimated for the Proposed Action.

Preclosure radiological impacts to the public. The likelihood that the maximally exposed individual would experience a latent cancer fatality would be less than 0.0006 for emplacement of Inventory Module 1 or 2, the same as for the Proposed Action. As for the Proposed Action, over 99 percent of this impact would result from the release of naturally occurring radon.

Postclosure radiological impacts. Postclosure cumulative impacts to public health could occur from radionuclides released from Yucca Mountain, from past weapons testing on the Nevada Test Site, and from past, present, and future disposal of radioactive waste in disposal sites on the Nevada Test Site and in regulated facilities near Beatty, Nevada. The mean annual dose estimated to occur within 10,000 years from disposal of the Proposed Action inventory is 0.24 millirem per year to the RMEI. Since the Module 1 inventory of commercial spent nuclear fuel would be approximately twice that of the Proposed Action, the mean annual dose resulting from disposal of the Module 1 inventory is also estimated to double. Module 2 impacts would add an additional fraction of 1 percent to the Module 1 impacts. As illustrated in the Yucca Mountain FEIS, the past weapons testing and radioactive waste disposal actions are not expected to make an additional noticeable contribution to the cumulative postclosure radiological impacts.

S.5.3 TRANSPORTATION

The SEIS analysis assumes that, to ship Inventory Module 1 or 2 to the repository, DOE would use the transportation routes described for the Proposed Action and would make a larger number of shipments, over a longer period of time. This would result in increased industrial hazards, traffic fatalities, and latent cancer fatalities. Impacts for national transportation for the Proposed Action are estimated to be about 8 total fatalities. For Module 1, DOE estimates about 18 total fatalities and for Module 2 about 19 total fatalities. The majority (about 80 percent) would be from radiation exposure of workers and traffic fatalities.

Additional impacts would result from transportation of construction materials, repository components, and consumables to the repository; workers who commute to the repository; and transportation of site-generated waste from the repository. Under the Proposed Action, DOE estimates there would be about 13 fatalities from exposure to vehicle emissions and 44 to 46 traffic fatalities. For Module 1 or 2, DOE estimates an increase to about 14 fatalities from exposure to vehicle emissions and 47 to 50 traffic fatalities.

During the national transportation of radioactive materials from 1943 to 2073 *not* associated with the Proposed Action, DOE estimated that there would be about 220 latent cancer fatalities among exposed workers and about 210 latent cancer fatalities among exposed members of the public. When these impacts were combined with the impacts of the Proposed Action, Module 1, and Module 2, DOE estimated that there would be about 230 latent cancer fatalities among exposed workers and about 210 latent cancer fatalities among exposed members of the public.

During the national transportation of radiological materials from 1943 to 2073 not associated with the Proposed Action, DOE estimated that there would be about 100 traffic fatalities. When these impacts were combined with the impacts of the Proposed Action, Module 1, and Module 2, DOE estimated that there would be about 100 to 110 traffic fatalities.

S.6 Mitigating Potential Adverse Environmental Impacts

DOE is fully committed to sound stewardship practices that protect the resource areas analyzed in this Repository SEIS. It has applied monitoring and mitigation measures throughout the Yucca Mountain Project. For the Proposed Action, DOE would meet this commitment by adapting and expanding its Environmental Management System for the repository project, as part of its existing Integrated Safety Management System. That system is designed to ensure that DOE achieves its missions while protecting the public, workers, and the environment. The structured framework provided by an Environmental Management System permits the systematic identification, evaluation, and mitigation of environmental impacts. As stated by the Council on Environmental Quality, Environmental Management Systems and NEPA are complementary processes.

As part of the planning process, DOE would establish measurable environmental objectives and set measurable goals and targets tailored to the Proposed Action (for example pollution prevention goals for reductions in waste generation). DOE would then implement programs, procedures, and controls for monitoring and measuring progress. It would document progress and, if appropriate, determine appropriate mitigation measures and implement them.

In implementing the Proposed Action, DOE would adhere to NRC safety requirements in 10 CFR Part 63 for the construction, operation, monitoring, and closure of a geologic repository and meet or exceed the requirements of 10 CFR Part 71 for the transportation of spent nuclear fuel and high-level radioactive waste. The incorporation of safety factors and controls in the engineering design and operational procedures would help prevent accidents and thereby minimize potential releases to the environment.

DOE would implement best management practices to mitigate potential environmental impacts it identified during construction, operation, monitoring, and closure of the repository.

S.7 Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitments of Resources

The construction, operation, monitoring, and eventual closure of the proposed Yucca Mountain repository and the associated transportation of spent nuclear fuel and high-level radioactive waste could produce some environmental impacts that DOE could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources.

- The permanent withdrawal of approximately 600 square kilometers (230 square miles) of land for the repository would be likely to prevent human use of the withdrawn lands for other purposes.

- Death or displacement of individual members of some animal species, including the desert tortoise, as a result of site clearing and vehicle traffic would be unavoidable.

- Injuries to workers or worker fatalities could result from facility construction and operation.

- Transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public through exposure to radiation and vehicle emissions, and through traffic accidents.

- Electric power, fossil fuels, and construction materials would be irreversibly committed to the project.

- DOE would use fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository.

Further, in the view of American Indian tribes in the Yucca Mountain region, construction of the proposed repository and related facilities would degrade the environmental setting. Even after repository closure and site reclamation, the presence of the repository would, from their perspective, result in an irreversible impact to traditional lands and values.

S.8 Statutory and Other Applicable Requirements

Many statutes and regulations would apply to the licensing, development, operation, and closure of a geologic repository. These include the NWPA, NEPA, the *Atomic Energy Act*, the *Federal Land Policy and Management Act of 1976*, site-specific public health and environmental radiation protection standards established by EPA, site-specific technical licensing regulations established by NRC, and site suitability guidelines established by DOE.

DOE is subject to other requirements, including those promulgated under the *Clean Air Act; Clean Water Act; Emergency Planning and Community Right-to-Know Act of 1986; National Historic Preservation Act; Archaeological Resources Protection Act; Endangered Species Act;* and applicable Nevada statutes and regulations. In accordance with federal authorities, DOE would apply for new permits, licenses, and approvals to construct, operate, monitor, and eventually close the proposed Yucca Mountain Repository.

Under the authority of the *Atomic Energy Act*, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. Under Executive Order 13148, DOE is responsible for developing and implementing an Environmental Management System. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Because NRC is authorized to license the proposed Yucca Mountain repository, DOE issued Order 250.1 exempting such a repository from compliance with provisions of DOE Orders that overlap or duplicate NRC licensing requirements.

DOE has interacted with agencies authorized to issue permits, licenses, and other regulatory approvals, as well as those responsible for protecting such significant resources as endangered species, wetlands, or historic properties. DOE also has coordinated with the affected units of local government, NRC, U.S. Air Force, U.S. Navy, U.S. Department of Agriculture, U.S. Department of Transportation, EPA, U.S. Department of the Interior including its Bureaus (U.S. Fish and Wildlife Service, National Park Service, and Bureau of Land Management), the Council on Environmental Quality, Nevada Department of Transportation, and Native American tribes.

S.9 Conclusions

S.9.1 MAJOR CONCLUSIONS OF THE REPOSITORY SEIS

The Proposed Action would cause preclosure environmental impacts from construction, operation, monitoring, and closure of the repository. There could also be postclosure impacts to the health and safety of future generations. The preclosure and postclosure impacts from the repository are provided in Table S-1. Potential impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste nationally and in Nevada are presented in Table S-2. These impacts include those estimated for the construction and operation of a railroad in Nevada.

As reported in Table S-1, the Repository SEIS analysis demonstrated that the postclosure performance of the proposed repository over the first 10,000 years after closure would result in a mean and median annual individual dose that would not exceed 0.24 millirem and 0.12 millirem, respectively, to the RMEI hypothetically located 18 kilometers (11 miles) from the repository. The analysis of the post-10,000-year period resulted in a mean and median annual individual dose that would not exceed 2.3 millirem and 0.98 millirem, respectively, to the RMEI at the same location. There would be no adverse health effects to individuals from these projected doses.

Estimated impacts of the No-Action Alternative are presented in Table S-3 to provide a basis of comparison with the Proposed Action.

The compilation of all preclosure impacts resulting from the repository and National and Nevada transportation is presented in Table S-4. The table illustrates the aggregation of impacts within each resource area that overlap within the repository region of influence.

Considering the preclosure and postclosure impacts presented in this Repository SEIS, DOE concludes that the potential impacts associated with the current repository design and operational plans are similar in scale to impacts presented in the Yucca Mountain FEIS.

S.9.2 AREAS OF CONTROVERSY

In the Yucca Mountain FEIS, DOE acknowledged that areas of controversy exist regarding the Proposed Action and the analyses of its impacts. DOE believes that several of these areas remain of concern and reflect differing points of view or irreducible uncertainties.

Table S-1. Potential preclosure and postclosure impacts from repository construction, operations, monitoring, and closure.

Resource area	Preclosure impacts	Postclosure impacts
Land use and ownership	Small; about 9.1 km^2 (2,200 acres) of disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use.	Small; potential for limited access into the area; reclamation of disturbed land would restore preconstruction conditions; the only surface features remaining would be markers.
Air quality	Small; releases well below regulatory limits (less than 3 percent) for all criteria pollutants except particulate matter. Maximum releases of PM_{10} would be 40 percent of limit at land withdrawal area boundary.	Small; population doses from release of gaseous radionuclides would be on the order of 1×10^{-8} person-rem in the 80-km (50-mile) radius around the repository.
Hydrology		
Surface water	Small; land disturbance would result in minor changes to runoff and infiltration rates; minimal potential for contaminants to be released and reach surface water; only ephemeral drainage channels would be affected. Facilities would be constructed above flood zones or diversion channels would be constructed to keep flood waters away; floodplain assessment concluded impacts would be small.	Small; potential sources for surface water contamination would no longer be present.
Groundwater	Small to moderate; minimal potential to change recharge rates and for contaminants to be released and reach groundwater; peak water demand (430 acre-feet per year) below the lowest estimate of the groundwater basin's perennial yield (580 acre-feet); after construction, water demand would decrease to 260 acre-feet per year or less. Groundwater would be withdrawn from existing wells and possibly a new well to support Gate 510 facilities.	Estimated releases over the first 10,000 years would result in a mean and median annual individual dose that would not exceed 0.24 millirem and 0.12 millirem, respectively, to an RMEI hypothetically located 18 kilometers (11 miles) from the repository. The analysis of the post-10,000-year period resulted in a mean and median annual individual dose that would not exceed 2.3 millirem and 0.98 millirem, respectively, to the RMEI at the same location. Expected uptakes from nonradioactive hazardous chemicals would all be less than the Oral Reference Doses for any of these substances.
Biological resources and soils	Small; loss of up to 9.1 km^2 (2,200 acres) of desert soil, habitat, and vegetation, but no loss of rare or unique habitat or vegetation; adverse impacts to individual threatened desert tortoises and loss of a small amount of low-density tortoise habitat, but no adverse impacts to the species as a whole; reasonable and prudent measures would minimize impacts; no adverse impacts to wetlands.	Small; slight increase in surface soil temperature directly over repository, lasting from approximately 200 to 10,000 years, could result in a temporary shift in plant and animal communities in the affected area; impacts to individual threatened desert tortoises would decrease as activity level at repository decreased; no temperature-driven change in desert tortoise sex-ratio would be likely; sediment load in ephemeral water courses could temporarily increase coincident with changes to soil and vegetation characteristics.

Table S-1. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Cultural resources	Small; ground disturbances and activities that could destroy or modify the integrity of archaeological or cultural resource sites would be minimized through avoidance of sites and mitigation. Indirect impacts that could result from easier physical access to the land withdrawal area, such as unauthorized excavation and collection of artifacts, would be mitigated by training, monitoring and establishing long-term management of sites. Opposing Native American viewpoint exists.	Small; potential for limited access into the area; opposing American Indian viewpoint.
Socioeconomics		
New jobs (percent of workforce in affected counties)	Construction: Small impacts in region; peaks are 0.05 percent above baseline in Clark County and 1.52 percent above baseline in Nye County.	Small; no workers, no impacts.
	Operations: Small impacts in region; peaks are 0.06 percent above baseline in Clark County and 2.0 percent above baseline in Nye County.	
Peak real disposable income (million dollars)	Construction: Small impacts in region; peaks are $41.7 million (0.05-percent increase) in Clark County and $17.1 million (1.16-percent increase) in Nye County.	Small; no workers, no impacts.
	Operations: Small impacts in region; peaks are $58.3 million (0.05-percent increase) in Clark County and $27.7 million (1.15-percent increase) in Nye County.	
Peak incremental Gross Regional Product (million dollars)	Construction: Small impacts in region; peaks are $58.9 million (0.05-percent increase) in Clark County and $22.7 million (1.42-percent increase) in Nye County.	Small; no workers, no impacts.
	Operations: Small impact in region; peaks are $98.7 million (0.05-percent increase) in Clark County and $68.9 million (2.65-percent increase) in Nye County.	
Occupational and public health and safety		
Public, Radiological		
MEI (probability of an LCF)	0.00029	1.4×10^{-7}
Population (LCFs)	8	Not calculated.

Table S-1. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Occupational and public health and safety (continued)		
Public, Nonradiological		
Fatalities due to emissions	Small; exposures well below regulatory limits.	Small; exposures well below regulatory limits.
Workers (involved and noninvolved)		
Radiological (LCFs)	4.4	No workers; no impacts.
Nonradiological fatalities (includes commuting traffic fatalities)	37	No workers; no impacts.
Accidents, Radiological		
Public MEI (probability of an LCF)	7.2×10^{-11} to 1.4×10^{-5}	Not applicable.
Public Population (LCFs)	2.6×10^{-7} to 0.16	Not applicable.
Workers	6.6×10^{-5} to 2.3 rem (4.0×10^{-8} to 1.4×10^{-3} LCF)	Not applicable.
Noise and vibration	Small; impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels—controls and protection would be used as necessary.	Small; no activities, therefore, no noise or ground vibration.
Aesthetics	Small; the presence of exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several kilometers, especially west of Yucca Mountain.	Small; the only constructed surface features remaining would be markers.
Utilities, energy, materials, and site services	Small; use of materials would be small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would need enhancement.	Small; no use of materials or energy.

Table S-1. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Waste and hazardous materials	Construction/demolition debris – 476,000 cubic meters (AA cubic yards) Industrial wastewater – 1.2 million cubic meters (BB gallons) Sanitary sewage – 2.0 million cubic meters (CC gallons) Sanitary/industrial waste – 100,000 cubic meters (DD cubic yards) Hazardous waste – 8,900 cubic meters (EE cubic yards) Low-level radioactive waste – 7,400 cubic meters (FF cubic yards) None of the projected volumes of waste would exceed regional capacities for disposal or management.	Small; no waste generated or hazardous materials used.
Environmental justice	No identified high and adverse potential impact to population; no identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. DOE acknowledges the opposing American Indian viewpoint.	Small; no disproportionately high and adverse impacts to minorities or low-income populations; opposing American Indian viewpoint.
Airspace restrictions	Small; if deemed necessary, DOE would obtain exclusive control of a lightly used 48-km^2 (19 square miles) airspace and implement specific restrictions to the Nevada Test Site restricted airspace; airspace restrictions could be lifted once operations were complete.	Not applicable.
Manufacturing repository components		
Air quality	Small; annual pollutant emissions from component manufacturing would be 0.4 percent or less of the regional emissions for a typical manufacturing location.	Not applicable.
Occupational and public health and safety	Small; 1,700 reportable occupational injuries and illnesses and 0.61 fatality over entire manufacturing campaign.	Not applicable.
Socioeconomics	Moderate; the area of a typical manufacturing site could see increases of up to 4.6 percent in the average annual output; up to 2.5 percent in the average annual income; and up to 0.63 percent in the average annual employment.	Not applicable.

Table S-1. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Materials use	Moderate; annual use of chromium and nickel in component manufacturing would each be roughly 3 percent of U.S. production, or imports in the case of nickel. Annual use of titanium would be 22 percent of U.S. imports in 2006 when there was limited domestic production, but increased domestic production is forecast for the future.	Not applicable.
Waste generation	Small; a typical manufacturing facility would generate 7.5 metric tons (8.3 tons) of liquid waste and 1 metric ton (1.1 tons) of solid waste per year.	Not applicable.
Environmental justice	Disproportionately high and adverse impacts to minority or low-income populations would be unlikely from the manufacturing activities.	Not applicable.

km = kilometer.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.

Table S-2. Potential impacts from national and Nevada transportation.

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Corridor length		Total length (all new construction): 528 to 541 km (328 to 336 miles).	Total length: 452 to 502 kilometers (281 to 312 miles).
Land use and ownership	Small[b]	Total surface disturbance: 55 to 61 km^2 (14,000 to 15,000 acres); would result in topsoil loss and increased potential for erosion.	Total surface disturbance: 40 to 48 km^2 (9,900 to 12,000 acres) would result in topsoil loss and increased potential for erosion.
		Loss of prime farmland soils: 1.3 to 1.8 km^2 (320 to 440 acres). Less than 0.1 percent of prime farmland soils in Lincoln and Nye counties.	Loss of prime farmland soils: 0.011 to 0.014 km^2 (2.7 to 3.5 acres). Less than 3 percent of the prime farmland soils of the Walker River Paiute Reservation.
		Land use change on public lands for operations right-of-way.	Land use change on public lands and on Walker River Paiute Reservation for operations right-of-way.
		Private parcels the rail line would cross: 14 to 71. Area of affected private land: 0.33 to 0.72 km^2 (82 to 178 acres).	Private parcels the rail line would cross: 1 to 40. Area of affected private land: 0.21 to 0.59 km^2 (52 to 146 acres).
		Active grazing allotments the rail line would cross: 24 to 27. Animal unit months lost: 1,019 to 1,050. (An animal unit month represents enough dry forage for one mature cow for 1 month.)	Active grazing allotments the rail line would cross: 5 to 8. Animal unit months lost: 159 to 246.
		Sections with unpatented mining claims that would be crossed: 32 to 37.	Sections with unpatented mining claims that would be crossed: 23 to 30.
Air quality	Small[b]	Rail line construction would result in PM_{10}, $PM_{2.5}$, and NO_x, increases greater than the 2002 county-wide burden for Lincoln and Nye Counties and in NO_x increase greater than the 2002 county-wide burden for Esmeralda County. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded.	Rail line construction would result in CO, VOC, $PM_{2.5}$, PM_{10}, and NO_x increases greater than the 2002 county-wide burden for Esmeralda County; NO_x increase greater than the 2002 county-wide burden for Nye County; and CO, $PM_{2.5}$, PM_{10} and NO_x increases greater than the 2002 county-wide burdens for Mineral County. Rail line construction would not add any criteria air pollutants greater than the 2002 county-wide burden for Churchill and Lyon counties. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded.
		Rail line operations would add less than about 20 percent to the 2002 county-wide burden of all criteria air pollutants for Lincoln County, less than 6 percent for Esmeralda County, and less than 40 percent for Nye County. Rail line operations would not lead to an exceedance of air quality standards. Construction and operation of a proposed quarry in Lincoln County would not result in exceedances of the NAAQS.	Rail line operations would add less than 35 percent to the 2002 county-wide burden of all criteria air pollutants for both Esmeralda and Nye counties and less than about 1 percent to the 2002 county-wide burden of all criteria air pollutants for Churchill and Lyon counties.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Air quality (continued)			Rail line operations would add less than about 2 percent to the 2002 county-wide emissions for SO_2, CO, $PM_{2.5}$, PM_{10} and VOCs and about 80 percent for NO_x emissions for Mineral County. Rail line operations would not lead to an exceedance of air quality standards.
		Construction and operation of a proposed quarry in Nye County could result in exceeding 24-hour PM_{10} limit, but measures required by the Surface Disturbance Permit would greatly reduce PM_{10} emissions making an exceedance of the NAAQS unlikely. Churchill County. Not applicable. Lyon County. Not applicable. Mineral County. Not applicable.	Operation of a quarry in Esmeralda County during construction of the rail line shows no air pollutant would exceed 60 percent of the NAAQS for any averaging period. Operation of a proposed quarry in Mineral County could result in exceeding 24-hour PM_{10} and $PM_{2.5}$ standards, but measures required by the Surface Disturbance Permit would greatly reduce PM_{10} and $PM_{2.5}$ emissions making exceedances of the NAAQS unlikely. Construction of the Staging Yard at Hawthorne in Mineral County could result in exceeding 24-hour PM_{10} and $PM_{2.5}$ standards in the immediate vicinity under some conditions. Lincoln County. Not applicable.
Hydrology			
Surface water	Small[b]	Approximately 0.33 km^2 (81 acres) of wetlands could be filled.	Not more than 28 m^2 (300 square feet) of wetlands would be filled.
Groundwater	Small[b]	Physical impacts to existing groundwater resource features such as existing wells or springs resulting from railroad construction and operation would be small.	Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operations would be small.
		Groundwater withdrawals during construction in some areas could impact existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts.	Groundwater withdrawals during construction in some areas could affect existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]: Caliente implementing alternative	Nevada transportation[a]: Mina implementing alternative
Hydrology (continued)		The impact of proposed groundwater withdrawals on groundwater quality would be small to negligible. The proposed withdrawals would not conflict with water quality standards protecting groundwater resources.	The impact of proposed groundwater withdrawals on groundwater quality would be small to negligible. The proposed withdrawals would not conflict with water quality standards for groundwater resources.
Biological resources	Small[b]	Short-term impact to 0.12 to 0.24 km^2 (30 to 59 acres) wetland/riparian habitat. Long-term impact to 0.11 to 0.23 km^2 (27 to 57 acres) wetland/riparian habitat. Impacts would vary by alternative segment, be localized, and could include: • Short-term moderate impact on riparian • and wetland vegetation • Long-term moderate impacts on riparian and wetland vegetation • Small to moderate impacts on raptor nesting sites • Short-term moderate impacts to desert big horn sheep	Short-term impact to 0.01 to 0.05 km^2 (2.5 to 12 acres) wetland/riparian habitat. Long-term impact up to 0.01 km^2 (0 to 2.5) wetland/riparian habitat. Impacts would vary by alternative segment, be localized, and could include: • Short-term moderate impact on riparian and wetland vegetation • Short-term moderate impacts to Lahontan cutthroat trout • Small to moderate long-term impacts to Inter-Mountain mixed salt desert scrub and Inter-Mountain Basins Greasewood Flat • Moderate long-term impact to Inter-Mountain mixed salt desert scrub • Short-term and long-term moderate impacts to Western snowy plover • Moderate impact to winterfat communities • Long-term moderate impacts to Inter-Mountain Basins mixed salt desert scrub and Inter-Mountain Basins big sagebrush • Short-term moderate impacts to desert big horn sheep
Cultural resources	Small[b]	Numerous archaeological sites identified along segments of alignments subject to sample inventory. Construction could result in impacts to the early Mormon colonization cultural landscape, Pioche-Hiko silver mining community route, 1849 Emigrant Trail campsites, American Indian trail systems, and more than 50 National Register-eligible sites identified along segments of alignments subjected to sample inventory.. Indirect effects to a National Register-eligible rock art site are likely from two quarry sites. No direct impacts to known paleontological resources.	Numerous archaeological sites, including more than 60 National Register-eligible sites, identified along segments of alignments subject to sample inventory. Potential direct and indirect impacts to National Register-eligible sites and to other sites that might be identified during the complete survey. No direct impacts to known paleontological resources.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Socioeconomics			
New jobs (percent of workforce in affected counties	Small[b]	Construction: Ranges from 0.1-percent increase in Clark County to 5.6-percent increase in Lincoln County. Operation: Ranges from less than 0.1-percent increase in Clark County to 3.9-percent increase in Lincoln County.	Construction: Ranges from 0.02-percent increase in Lyon County to 14 -percent increase in Esmeralda County. Operation: Ranges from 0.01-percent increase in Lyon County to 14-percent increase in Esmeralda County.
Peak real disposable income (million dollars)	Small[b]	Construction: Ranges from 0.2-percent increase in Clark County to 7.6-percent increase in Esmeralda County. Operation: Ranges from less than 0.1-percent increase in Clark County to 4.7-percent increase in Lincoln County.	Construction: Ranges from 0.03-percent increase in Lyon County to 27-percent increase in Esmeralda County. Operation: Ranges from 0.01-percent increase in Lyon County to 10-percent increase in Esmeralda County.
Peak incremental Gross Regional Product (million dollars)	Small[b]	Construction: Ranges from 0.2-percent increase in Clark County to 28-percent increase in Lincoln County. Operation: Ranges less than 0.1-percent increase in Clark County to 5.2-percent increase in Lincoln County.	Construction: Ranges from 0.04-percent increase in Lyon County to 57-percent increase in Esmeralda County. Operation: Ranges less than 0.01-percent increase in Lyon County to 24-percent increase in Esmeralda County.
Occupational and public health and safety			
Public, Radiological			
MEI (probability of an LCF)	1.3×10^{-4}	4.7×10^{-6}	4.7×10^{-6}
Population (LCFs)	0.63 to 0.69	6.3×10^{-5} to 1.5×10^{-4}	8.2×10^{-4} to 8.6×10^{-4}
Workers (involved and noninvolved)			
MEI (probability of an LCF)[c]	0.015	0.015	0.015
Radiological (LCFs)	9.8 to 10	0.78	0.77 to 0.79
Nonradiological fatalities (includes commuting traffic and vehicle emissions fatalities)	63 to 65	21	22

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]: Caliente implementing alternative	Nevada transportation[a]: Mina implementing alternative
Noise and vibration	Small[b]	Noise from construction activities would exceed Federal Transit Administration guidelines in two locations. Noise from rail construction would be temporary. There would be no adverse noise or vibration impacts from construction trains or from operational train activity.	Noise impacts from construction would be considered temporary adverse impacts at two locations. Noise from operations would create adverse noise impacts at two locations. There would be no vibration impacts from construction trains or from operational train activity.
Aesthetics	Small[b]	Small to moderate impact along rail alignment (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, staging yard, and quarries.	Small to moderate impact along rail alignment (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, staging yard, and quarries.
Utilities, energy, materials, and site services	Small[b]	Utility interfaces: Potential for short-term interruption of service during construction. No permanent or long-term loss of service or prevention of future service area expansions.	Utility interfaces: Potential for short-term interruption of service during construction. No permanent or long-term loss of service or prevention of future service area expansions.
		Public water systems: Most water would be supplied by new wells; small effect on public water systems from population increase attributable to construction and operation employees.	Public water systems: Most water would be supplied by new wells; small effect on public water systems from population increase attributable to construction and operation employees.
		Wastewater systems: Dedicated wastewater treatment systems would be provided at construction camps and operations facilities; small impact on public systems from population increase attributable to construction and operation employees.	Wastewater systems: Dedicated wastewater treatment systems would be provided at construction camps and operations facilities; small impact on public systems from population increase attributable to construction and operation employees.
		Telecommunications: Dedicated telecommunication systems; minimal reliance on communications providers.	Telecommunications: Dedicated telecommunication systems; minimal reliance on communications providers.
		Electricity: Peak demand would be within capacity of regional providers.	Electricity: Peak demand would be within capacity of regional providers.
		Fossil fuels: Fossil-fuel demand would be approximately 6.5 percent of state-wide use during construction and less than 0.25 percent of state-wide use during operation. Demand could be met by existing regional supply systems and suppliers. For the Shared-Use Option, demand would be less than 0.3 percent of state-wide use during operation. Demand could be met by existing regional supply systems and suppliers.	Fossil fuels: Fossil-fuel demand would be approximately 6 percent of state-wide use during construction and less than 0.25 percent of statewide use during operation. Demand could be met by existing regional supply systems and suppliers. For the Shared-Use Option, demand would be less than 0.3 percent of state-wide use during operation. Demand could be met by existing regional supply systems and suppliers.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a] Caliente implementing alternative	Mina implementing alternative
Utilities, energy, materials, and site services (continued)		Materials: Material requirements such as steel, concrete, and ballast would generally be very small in relation to supply capacity.	Materials: Material requirements such as steel, concrete, and ballast would generally be very small in relation to supply capacity.
Hazardous materials and waste	Small[b]	Small (Apex Landfill) to moderate (smaller landfills) impacts from nonhazardous waste (solid and industrial and special waste) disposal. Small impacts from use of hazardous materials. Small impacts from hazardous waste disposal. Small impacts from low-level radioactive waste disposal for wastes that would be generated at the Cask Maintenance Facility.	Small (Apex Landfill) to moderate (smaller landfills) impacts from nonhazardous waste (solid and industrial and special waste) disposal. Small impacts from use of hazardous materials. Small impacts from hazardous waste disposal. Small impacts from low-level radioactive waste disposal for wastes that would be generated at the Cask Maintenance Facility.
Environmental justice	Small[b]	Constructing and operating the proposed rail line along the Caliente rail alignment would not result in disproportionately high and adverse impacts to minority or low-income populations.	Constructing and operating the proposed rail line along the Mina rail alignment would not result in disproportionately high and adverse impacts to minority or low-income populations.

a. Short-term impacts for the Rail Alignment EIS would occur during the construction phase (4 to 10 years). Long-term impacts would occur throughout and beyond the life of the railroad operations phase (up to 50 years).

b. With the exception of occupational and public health and safety impacts, because shipments of spent nuclear fuel and high-level radioactive waste would comprise only small fractions of total national highway and rail traffic, the environmental impacts of the shipments on land use and ownership; *hydrology*; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small in comparison to the impacts of other nationwide transportation activities

c. Based on a worker who would receive the administrative dose limit of 500 millirem per year.

CO = Carbon monoxide.
km = kilometer.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NAAQS = National Ambient Air Quality Standards.
NO_x = Nitrous oxides.
SO_2 = Sulfur dioxide.
VOC = Volatile organic compounds.

Table S-3. Potential impacts from the No-Action Alternative.

Resource area	Repository	Commercial and DOE sites: Short-term 100 years	Commercial and DOE sites: Long-term (100 to 10,000 years) Scenario 1	Commercial and DOE sites: Long-term (100 to 10,000 years) Scenario 2
Land use and ownership	DOE would require no new land to support decommissioning and reclamation. Decommissioning and reclamation would include removal or shutdown of existing surface and subsurface facilities and restoration of disturbed lands, including soil stabilization and revegetation of disturbed areas.	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential contamination of 0.04 to 0.4 km^2 (9.8 – 98 acres) around each of the existing commercial and DOE sites.
Air quality	Dismantling and removal of existing structures, recontouring, and revegetation would generate fugitive dust that would be below the regulatory limit.	Small; releases and exposures well below regulatory limits.	Small; releases and exposures well below regulatory limits.	Small; degraded facilities would preclude large atmospheric releases.
Hydrology				
Surface water	Recontouring of terrain to restore the natural drainage and manage potential surface-water contaminant sources would minimize surface-water impacts.	Small; minor changes to runoff and infiltration rates.	Small; runoff during storage and reconstruction would be controlled in storm water holding ponds; active monitoring would ensure quick response to leaks or releases; commercial and DOE sites for storage likely would be outside of flood zones.	Large; potential for radiological releases and contamination of drainage basins downstream of commercial and DOE sites (concentrations potentially exceeding current regulatory limits).
Groundwater	DOE would use a small amount of groundwater during the decommissioning and reclamation.	Small, use would be small in comparison with other site use.	Small; use would be small in comparison with other site use.	Large; potential for radiological contamination of groundwater around the commercial and DOE sites.
Biological resources and soils	Reclamation would result in the restoration of 1.4 km^2 (346 acres) of habitat. Site reclamation would include soil stabilization and revegetation of disturbed areas. Some animal species could take advantage of abandoned tunnels for shelter. Decommissioning and reclamation could produce adverse impacts to the threatened desert tortoise.	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential adverse impacts at each of the sites from subsurface contamination of 0.04 to 0.4 km^2 (9.8 – 98 acres).

Table S-3. Potential impacts from the No-Action Alternative (continued).

		Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	100 years	Scenario 1	Scenario 2
Cultural resources	Leaving roads in place after decommissioning could have an adverse impact on cultural resources by increasing public access to the site. Preserving the integrity of important archeological sites and resources important to American Indians could be difficult.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; no construction or operation activities; therefore, no impacts.
Socioeconomics	Loss of approximately 4,700 jobs (1,800-person workforce for decommissioning and reclamation, 1,400-person engineering and technical personnel in locations other than the repository site, and 1,500 indirect jobs) in the socioeconomic region of influence. Nye County collects most of the federal monies associated with the repository project. The No-Action Alternative would result in the loss of payments-in-lieu-of-taxes to Nye County.	Small; population and employment changes would be small compared with totals in the regions.	Small; population and employment changes would be small compared with totals in the regions.	No workers; therefore, no impacts
Occupational and public health and safety				
Public – Radiological MEI (probability of an LCF)		5.2×10^{-6}[(a)]	1.6×10^{-6}[(a)]	(b)
Public – Population (LCFs)	0.001	0.49[a]	3.1[a]	1,000[c]
Public – Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Moderate to large; substantial increases in releases of hazardous substances and exposures to the public.
Workers – Radiological (LCFs)	0.09	24[a]	15[a]	No workers; therefore, no impacts.
Workers – Nonradiological fatalities (includes commuting traffic fatalities)	Less than 0.15	9	1,080	No workers; therefore, no impacts.

Table S-3. Potential impacts from the No-Action Alternative (continued).

Resource area	Repository	Commercial and DOE sites: Short-term 100 years	Commercial and DOE sites: Long-term (100 to 10,000 years) Scenario 1	Commercial and DOE sites: Long-term (100 to 10,000 years) Scenario 2
Accidents				
Public – Radiological MEI (probability of an LCF)	None	None	None	Not applicable.
Public – Population (LCFs)	None	None.	None.	4 to 16[d]
Workers	Accident impacts would be limited to those from traffic and typical industrial hazards during construction or excavation activities. These were estimated at 94 total recordable cases and 45 lost workday cases.	Large; for some unlikely accident scenarios workers probably would be severely injured or killed; however, DOE or NRC would manage facilities safely during continued storage operations.	Large; for some unlikely accident scenarios workers would probably be severely injured or killed.	No workers; therefore, no impacts
Traffic and transportation	Less than 0.15 traffic fatality would be likely during decommissioning and reclamation.	Small; local traffic only.	Small; local traffic only.	No activities, therefore no traffic.
Noise and vibration	Noise levels would be no greater than the current baseline noise environment at the Yucca Mountain site.	Small; transient and not excessive, less than 85 dBA.	Small; transient and not excessive, less than 85 dBA.	No activities, therefore, no noise.
Aesthetics	Site decommissioning and reclamation would improve the scenic value of the site, which DOE would return as close as possible to its predisturbance state.	Small; storage would continue at existing sites; expansion as needed.	Small; storage would continue at existing sites, with expansion as needed.	Small; aesthetic value would decrease as facilities degraded.
Utilities, energy, materials, and site services	Decommissioning would consume electricity, diesel fuel, and gasoline. The amounts of use would not adversely affect the utility, energy, or material resources of the region.	Small; materials and energy use would be small in comparison to total regional use.	Small; materials and energy use would be small in comparison to total regional use.	No use of materials or energy; therefore, no impacts.
Waste management	Decommissioning would generate some waste that would require disposal in existing Nevada Test Site landfills. DOE would minimize waste by salvaging most equipment and many materials.	Small; waste generated and materials used would be small in comparison to total regional generation and use.	Small; waste generated and materials used would be small in comparison to total regional generation and use.	No generation of waste or use of hazardous materials; therefore, no impacts.

Table S-3. Potential impacts from the No-Action Alternative (continued).

		Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	100 years	Scenario 1	Scenario 2
Environmental justice	The No-Action Alternative at the repository location would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative during the first 100 years at commercial and DOE sites would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative under Scenario 1 at commercial and DOE sites would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative under Scenario 2 at commercial and DOE sites could potentially result in disproportionately high and adverse impacts to minority or low-income populations.

a. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem; no change to external dose coefficients.
b. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death could be caused by acute direct radiation exposure.
c. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem and ingestion dose coefficients that overall are about 25 percent of the coefficients for the Yucca Mountain FEIS.
d. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem and inhalation dose coefficients that are approximately the same as coefficients for the Yucca Mountain FEIS.

dBA = A-weighted decibels.
DOE = U.S. Department of Energy.
FEIS = Yucca Mountain Final Environmental Impact Statement.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
SEIS = Repository Supplemental Environmental Impact Statement.

Table S-4. Summary of potential preclosure impacts of the Proposed Action.[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts resulting from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts that occur within overlapping regions of influence
Land use and ownership	Approximately 49 to 70 km^2 (12,000 to 17,000 acres) of total disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use. Loss of prime farmland soils would range from 0.011 to 1.8 km^2, (2.7 to 440 acres) which would be less than 0.1 percent of prime farmland soils in Lincoln and Nye Counties and less than 3 percent of the prime farmland soils of the Walker River Paiute Reservation. Land use change would occur on public lands and on Walker River Paiute Reservation for operations right-of-way. Private parcels the rail line would cross would range from 1 to 71; area of private land affected would range from 0.21 to 0.72 km^2 (52 to 178 acres). Active grazing allotments the rail line would cross would range from 5 to 27. Animal unit months lost would range from 159 to 1,050. Sections with unpatented mining claims that would be crossed would range from 23 to 37.	About 12 km^2 (3,000 acres) of disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use.
Air quality	Releases from construction and operation of the repository would be well below regulatory limits (less than 3 percent) for all criteria pollutants except particulate matter. Maximum releases of PM_{10} would be 40 percent of limit at boundary of land withdrawal area. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded. Rail line operations would not lead to an exceedance of air quality standards.	Nye County is the only location where Nevada transportation impacts would overlap the repository region of influence. The Nevada transportation emissions would be distributed over the entire county and only the southern portion of the emissions from Nye County would be within the repository region of influence. Modeled concentrations of criteria pollutants at the boundary of the land withdrawal area would not exceed regulatory limits during simultaneous construction of the repository and railroad. Concentrations of all criteria pollutants except for particulate matter would be less than 6 percent of the regulatory limit. Concentrations of $PM_{2.5}$ would not exceed 37 percent, and concentrations of PM_{10} would not exceed 84 percent of the regulatory limit. The simultaneous operation of the repository and railroad would not exceed regulatory limits.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts resulting from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts that occur within overlapping regions of influence
Hydrology		
Surface water	Repository land disturbance would result in minor changes to runoff and infiltration rates. At repository site, potential for contaminants to be released and reach surface water would be minimal; only ephemeral drainage channels would be affected, there are no other surface-water resources at the site. Repository facilities would be constructed above flood zones or diversion channels would be constructed to keep flood waters away; floodplain assessment concluded impacts would be small. Up to 0.33 km^2 (81 acres) of wetlands could be filled.	At least two of the drainage channels and floodplains (Busted Butte Wash and Drill Hole Wash) crossed by the railroad would also be affected by construction of repository surface facilities.
Groundwater	Potential for repository actions to change recharge rates and for contaminants to be released and reach groundwater would be minimal. Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operation would be small. Repository peak water demand (430 acre-feet per year) would be below the lowest estimate of perennial yield (580 acre-feet) for the western two-thirds of the groundwater basin; after construction water demand would decrease to 260 acre-feet per year or less. Groundwater withdrawals during rail construction in some areas could affect existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts. Groundwater for repository facility use would be withdrawn from wells in Jackass Flats. Groundwater for rail construction would mostly be withdrawn from new wells.	Water identified for rail line construction includes 572 acre-feet (over four years) plus 6 acre-feet per year for operations, all from the same groundwater basin as for repository activities. A peak annual water demand of 640 acre-feet would result from the combined Nevada transportation and repository needs, assuming construction periods overlapped. This high level would last only 1 year and occur the year repository construction started. The average annual water demand for the combined construction period would be 440 acre-feet. With the exception of the first peak year, all of the combined water demand levels would be below the lowest estimate of perennial yield (580 acre-feet) for the western two-thirds of the groundwater basin. The year of highest water demand would not result in a well drawdown that could affect the nearest public or private wells. Modeling for the Yucca Mountain FEIS showed small to moderate impacts from the Proposed Action groundwater withdrawals that are still applicable. The model's assumed withdrawal rate of 430 acre-feet per year is lower than the peak water demand, but over the life of the project is still conservatively high.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Biological resources and soils	Loss of between 49 to 70 km^2 (12,000 to 17,000 acres) of desert soil, habitat, and vegetation. Adverse impacts to desert big horn sheep and special status species including Lahontan cutthroat trout, western snowy plover, and desert tortoise. Short-term impact of up to 0.24 km^2 (59 acres) wetland/riparian habitat. Long-term impact of up to 0.23 km^2 (57 acres) wetland/riparian habitat	Loss of up to 12 km^2 (3,000 acres) of desert soil, habitat, and vegetation, but no loss of rare or unique habitat or vegetation; adverse impacts to individual threatened desert tortoises and loss of a small amount of low-density tortoise habitat, but no adverse impacts to the species as a whole; reasonable and prudent measures would minimize impacts
Cultural resources	Numerous archaeological sites, up to 60 National Register-eligible sites, along segments of alignments subject to sample inventory and 3 sites in the repository region of influence. Opposing Native American viewpoint. Construction could result in impacts to the early Mormon colonization cultural landscape, Pioche-Hiko silver mining community route, 1849 Emigrant Trail campsites, American Indian trail systems. Indirect effects to a National Register-eligible rock art site are likely from two quarry sites. No direct impacts to known paleontological resources.	Small potential for impacts; including three National Register-eligible prehistoric sites; opposing Native American viewpoint.
Socioeconomics		
New jobs (percent of workforce in affected counties	Construction: Peaks range from 0.15 percent above baseline in Clark County to 14-percent increase in Esmeralda County. Operation: Peaks range from 0.01-percent increase in Lyon County to 14-percent increase in Esmeralda County.	Peak increases would be small, less than 1 percent in the region, Clark County, and Nye County when construction of repository and rail overlap.
Peak real disposable income (million dollars)	Construction: Peak percent increases are: • Nye: 1.16 (repository); 0.4 to 0.9 (rail) • Clark: 0.05 (repository); 0.1 (rail) • Lincoln: 4.1 (rail) • Esmeralda: 7.6 to 27 (rail) • Lyon: 0.03 (rail) • Walker River/Paiute Reservation: up to $386,000 • Mineral: 4.5 (rail) • Washoe County/Carson City: less than 0.3 (rail)	For Repository: In Clark County (2034), 58.3 million; in Nye County (2035) $27.5 million For Rail: In Clark County (2011) $100.6 million; in Nye County (2012) $9.6 million.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Socioeconomics (continued)		
	Operations: Peak percent increases are: • Nye: 1.15 (repository); 0.1 to 0.3 (rail) • Clark: 0.05 (repository); less than 0.1 (rail) • Lincoln: 4.7 (rail) • Esmeralda: 2.9 to 10 (rail) • Lyon: 0.01 (rail) • Walker River/Paiute Reservation: included in Mineral County • Mineral: 2.8 (rail) • Washoe County/Carson City: less than 0.1 (rail)	
Peak incremental Gross Regional Product (million dollars)	Construction: Peak percent increases are: • Nye: 1.42 (repository); 1.0 to 3.5 (rail) • Clark: 0.05 (repository); less than 0.1 to 0.1 (rail) • Lincoln: 28 (rail) • Esmeralda: 9.5 to 57 (rail) • Lyon: 0.04 (rail) • Walker River/Paiute Reservation: up to $1.4 million • Mineral: 14 (rail) • Washoe County/Carson City: less than 0.3 (rail) Operations: Peak percent increases are: • Nye: 2.65 (repository); 0.2 to 0.5 (rail) • Clark: 0.05 (repository); less than 0.1 (rail) • Lincoln: 5.2 (rail) • Esmeralda: 3.8 to 24 (rail) • Lyon: 0.01 (rail) • Walker River/Paiute Reservation: included in Mineral County • Mineral: 1.9 (rail) • Washoe County/Carson City: less than 0.1 (rail)	For Repository: In Clark County (2034), $98.7 million; in Nye County (2034) $68.9 million. For Rail: In Clark County (2012), $154.5 million; in Nye County (2012), $42.8 million

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Occupational and public health and safety		
Public, Radiological		
MEI (probability of an LCF)	2.9×10^{-4} (repository) 1.3×10^{-4} (transportation)	See Summary of all preclosure impacts column.
Population (LCFs)	8.6–8.7 (total)	See Summary of all preclosure impacts column.
Public, Nonradiological		
Fatalities due to emissions	Small; exposures well below regulatory limits.	Small; exposures well below regulatory limits.
Workers (involved and noninvolved)		
Radiological (LCFs)	14	See Summary of all preclosure impacts column.
Nonradiological fatalities (includes commuting traffic and vehicle emissions fatalities)	64 to 66 (total)	See Summary of all preclosure impacts column.
Accidents		
Public, Radiological		
MEI (probability of an LCF)	7.2×10^{-11} to 1.4×10^{-5}	See Summary of all preclosure impacts column.
Population (LCFs)	2.6×10^{-7} to 0.16	See Summary of all preclosure impacts column.
Workers, Radiological	6.6×10^{-5} to 2.3 rem (4.0×10^{-8} to 1.4×10^{-3} LCF)	See Summary of all preclosure impacts column.
Noise and vibration	Impacts to public would be low due to large distances from the repository to residences; workers exposed to elevated noise levels – controls and protection used as necessary. Noise from rail construction activities would exceed Federal Transit Administration guidelines in two locations. Noise from rail construction would be temporary. There would be no adverse vibration impacts from construction or operations.	Impacts to public would be low due to large distances from the repository to residences; workers exposed to elevated noise levels – controls and protection used as necessary.
Aesthetics	The exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several miles, especially west of Yucca Mountain. Aesthetic impacts would range from small to moderate along rail alignments (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, staging yard, and quarries.	The exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several miles, especially west of Yucca Mountain.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Utilities, energy, materials, and site services	Use of materials would be small in comparison to regional use; some effect on public water systems and public wastewater treatment facilities due to population growth from construction and operations employment; annual fossil-fuel use would be less than 7 percent of state-wide use during construction and less than 2 percent of state-wide use during operation; electric power delivery system to the Yucca Mountain site would have to be enhanced.	Use of materials would be small in comparison to regional use; some effect on public water systems and public wastewater treatment facilities due to population growth from construction and operations employment; annual fossil-fuel use would be less than 7 percent of state-wide use during construction and less than 2 percent of state-wide use during operation; electric power delivery system to the Yucca Mountain site would have to be enhanced.
Waste and hazardous materials	Small impacts from nonhazardous waste (solid and industrial waste) disposal to regional solid waste facilities. Small impacts from use of hazardous materials. Small impacts from hazardous-waste disposal to regional licensed hazardous waste facilities. Small impacts from low-level radioactive waste disposal to a DOE low-level waste disposal site, or Agreement State site, or an NRC-licensed site.	Small impacts from nonhazardous waste (solid and industrial waste) disposal to regional solid waste facilities. Small impacts from use of hazardous materials. Small impacts from hazardous-waste disposal to regional licensed hazardous waste facilities. Small impacts from low-level radioactive waste disposal to a DOE low-level waste disposal site, or Agreement State site, or an NRC-licensed site.
Environmental justice	No identified high and adverse potential impact to population; no identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. DOE acknowledges the opposing American Indian viewpoint.	Constructing and operating the proposed geologic repository at Yucca Mountain and constructing and operating the railroad to transport spend nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository would not result in disproportionately high and adverse impacts to minority or low-income populations.
Manufacturing repository components	Small impacts to all resources with the exception of moderate socioeconomic and materials impacts.	Not applicable.
Airspace restrictions	Small impact to airspace use; airspace restriction could be lifted once operations have been completed.	Small impacts to airspace use; airspace restriction could be lifted once operations have been completed.

a. Short-term impacts for the Rail Alignment EIS are impacts limited to the construction phase (4 to 10 years). Long-term impacts for the Rail Alignment EIS are impacts that could occur throughout and beyond the life of the railroad operations phase (up to 50 years).

DOE = U.S. Department of Energy.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.

S.9.2.1 American Indian Viewpoint

Certain American Indian tribes believe that the repository itself, regardless of its respective impacts, would adversely disturb the natural and cultural environment.

S.9.2.2 Transportation

Disagreement exists about factors relevant to the analyses of the potential environmental impacts from the transportation of spent nuclear fuel and high-level radioactive waste including for example, the specific routing chosen for analysis and the definition of the maximum reasonably foreseeable accident.

S.9.2.3 Evaluation of Postclosure Performance

Uncertainty exists about how to best represent the behavior of natural systems and complex engineered barriers in estimating repository performance over very long time periods extending hundreds of thousands of years into the future.

S.9.2.4 Water Rights

Water use and water development projects will continue to be a major concern in the region of influence regardless of the water demands associated with the proposed repository or the railroad. Growth in water demand in Nevada has been very rapid: water use against the backdrop of regional water transfer plans remains an overarching controversial issue.

S.9.3 ISSUES TO BE RESOLVED

For DOE to implement the Proposed Action, these primary issues would have to be resolved:

- DOE would have to complete an application for construction authorization, submit it to NRC, and fully satisfy NRC regulatory and licensing requirements.

- DOE would have to select a rail alignment for the railroad it would build and operate in Nevada and issue a Record of Decision documenting that selection.

- Congress would have to withdraw from public access the land that DOE would need to use for a repository, related facilities, and a buffer zone.

- EPA and NRC would have to finalize their proposed standards regarding the time of compliance for DOE's repository performance assessment.

Draft

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

Volume I Impact Analyses
Chapters 1 through 13

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250F-S1D

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Information about this document is available on the Internet at the Yucca Mountain Project web site at http://www.ocrwm.doe.gov and on the DOE National Environmental Policy Act (NEPA) web site at http://eh.doe.gov/nepa/.

ABSTRACT: DOE's Proposed Action is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. Under the Proposed Action, spent nuclear fuel and high-level radioactive waste in storage or projected to be generated at 72 commercial and 4 DOE sites would be shipped to the repository by rail (train), although some shipments would arrive at the repository by truck. The Draft Repository SEIS evaluates (1) the potential environmental impacts from the construction, operation and monitoring, and eventual closure of the repository; (2) potential long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste; (3) potential impacts of transporting these materials nationally and in the State of Nevada; and (4) potential impacts of not proceeding with the Proposed Action (the No-Action Alternative).

COOPERATING AGENCIES: Nye County, Nevada is a cooperating agency in the preparation of the Repository SEIS**.**

PUBLIC COMMENTS: A 90-day comment period on this document begins with the publication of the **Environmental** Protection Agency Notice of Availability in the Federal Register. DOE will consider comments received after the 90-day period to the extent practicable. The Department will hold public hearings to receive comments on the document at the times and locations announced in local media and the DOE Notice of Availability. Written comments may also be submitted by U.S. mail to the U.S. Department of Energy at the above address in Las Vegas, via the Internet at http://www.ymp.gov, or by facsimile at 1-800-967-0739. This public comment period and the public hearings coincide with those of the *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada – Nevada Rail Transportation Corridor* (DOE/EIS-0250F-S2D; the Nevada Rail Corridor SEIS), and *Draft Environmental Impact Statement for a Rail Alignment for the Construction and Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0369D; the Rail Alignment EIS).

FOREWORD

The U.S. Department of Energy (DOE or Department) has prepared two draft National Environmental Policy Act (NEPA) documents associated with the proposed disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository at the Yucca Mountain Site in Nye County, Nevada:

- *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS), and

- *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada – Nevada Rail Transportation Corridor* (Part 1) (DOE/EIS-0250F-S2D) (Nevada Rail Corridor SEIS) , and *Draft Environmental Impact Statement for a Rail Alignment for the Construction and Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain, Nye County, Nevada* (Part 2) (DOE/EIS-0369D) (Rail Alignment EIS).

The Repository SEIS evaluates the potential environmental impacts of constructing and operating the Yucca Mountain repository under the current repository design and operational plans, the purpose of which is to assist the U.S. Nuclear Regulatory Commission (NRC) in adopting, to the extent practicable, any EIS prepared pursuant to Section 114(f)(4) of the Nuclear Waste Policy Act, as amended (NWPA; 42 United States Code 10101 *et seq.*).

The Nevada Rail Corridor SEIS and Rail Alignment EIS evaluate the potential environmental impacts of constructing and operating a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to the repository at Yucca Mountain, the purpose of which is to help the Department decide whether to construct and operate a railroad, and if so, within which corridor and along which alignment.

Background and Context

The NWPA directs the Secretary of Energy, if the Secretary decides to recommend approval of the Yucca Mountain site for development of a repository, to submit a final EIS with any recommendation to the President. To fulfill that requirement, the Department prepared the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F, February 2002) (Yucca Mountain FEIS).

On February 14, 2002, the Secretary transmitted to the President his recommendation (including the Yucca Mountain FEIS) for approval of the Yucca Mountain site for development of a geologic repository. The President considered the site qualified for application to the NRC for construction authorization and recommended the site to the U.S. Congress. Subsequently, Congress passed a joint resolution of the U.S. House of Representatives and the U.S. Senate designating the Yucca Mountain site for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. On July 23, 2002, the President signed the joint resolution into law (Public Law 107-200). The Department is now in the process of preparing an application for submittal to the NRC seeking authorization to construct the repository, as required by the NWPA (Section 114(b)).

Since completion of the Yucca Mountain FEIS in 2002, DOE has continued to develop the repository design and associated construction and operational plans. As now proposed, the newly designed surface and subsurface facilities would allow DOE to operate the repository following a primarily canistered approach in which most commercial spent nuclear fuel would be packaged at the reactor sites in transportation, aging, and disposal (TAD) canisters. Any commercial spent nuclear fuel arriving at the repository in packages other than TAD canisters would be repackaged by DOE at the repository into TAD canisters. DOE would construct the surface and subsurface facilities over a period of several years (referred to as phased construction) to accommodate an increase in spent nuclear fuel and high-level radioactive waste receipt rates as repository operational capability reaches its design capacity. To address the current repository design and operational plans, the Department announced its intent to prepare a Supplement to the Yucca Mountain FEIS (DOE/EIS-0250F-S1), consistent with NEPA and the NWPA. (*Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV*; 71 FR 60490, October 13, 2006). The Repository SEIS supplements the Yucca Mountain FEIS by considering the potential environmental impacts of the construction, operation and closure of the repository under the current repository design and operational plans, and by updating the analysis and potential environmental impacts of transporting spent nuclear fuel and high-level radioactive waste to the repository, consistent with transportation-related decisions the Department made following completion of the Yucca Mountain FEIS.

On April 8, 2004, the Department issued a Record of Decision announcing its selection, both nationally and in the State of Nevada, of the mostly rail scenario analyzed in the Yucca Mountain FEIS as the primary means of transporting spent nuclear fuel and high-level radioactive waste to the repository (*Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV*; 69 FR 18557, April 8, 2004). Implementation of the mostly rail scenario ultimately would require the construction of a rail line to connect the repository site at Yucca Mountain to an existing rail line in the State of Nevada. To that end, in the same Record of Decision, the Department also selected the Caliente rail corridor from several corridors considered in the Yucca Mountain FEIS as the corridor in which to study possible alignments for a rail line. On the same day DOE selected the Caliente corridor, it issued a Notice of Intent to prepare an EIS under NEPA to study alternative alignments within the Caliente corridor (the Rail Alignment EIS; DOE/EIS-0369) (*Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*; 69 FR 18565, April 8, 2004).

During the subsequent public scoping process, DOE received comments suggesting that other rail corridors be considered, in particular, the Mina route. In the Yucca Mountain FEIS, DOE had considered but eliminated the Mina route from detailed study because a rail line within the Mina route could only connect to an existing rail line in Nevada by crossing the Walker River Paiute Reservation, and the Tribe had informed DOE that it would not allow nuclear waste to be transported across the Reservation.

Following review of the scoping comments, DOE held discussions with the Walker River Paiute Tribe and, in May 2006, the Tribal Council informed DOE that it would allow the Department to consider the potential impacts of transporting spent nuclear fuel and high-level radioactive waste across its reservation. On October 13, 2006, after a preliminary evaluation of the feasibility of the Mina rail corridor, DOE announced its intent to expand the scope of the Rail Alignment EIS to include the Mina corridor (*Amended Notice of Intent to Expand the Scope of the Environmental Impact Statement for the Alignment,* *Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*; 71 *FR* 60484). Although the expanded NEPA analyses, referred to as the Nevada Rail Corridor SEIS and Rail Alignment EIS, evaluate the potential environmental impacts associated with the Mina corridor, DOE has identified the Mina alternative as non-preferred because the Tribe has withdrawn its support for the EIS process.

Relationships among the EISs

The Yucca Mountain FEIS, the Repository SEIS and the Nevada Rail Corridor SEIS and Rail Alignment EIS are related in several respects. The Nevada Rail Corridor SEIS, supplements the rail corridor analysis of the Yucca Mountain FEIS by analyzing the potential environmental impacts associated with constructing and operating a railroad within the Mina corridor. The Nevada Rail Corridor SEIS analyzes the Mina corridor at a level of detail commensurate with that of the rail corridor analysis in the Yucca Mountain FEIS, and concludes that the Mina corridor warrants further study in the Rail Alignment EIS to identify an alignment for the construction and operation of a railroad.

The Nevada Rail Corridor SEIS also updates relevant information regarding three other rail corridors previously analyzed in the Yucca Mountain FEIS (Carlin, Jean, and Valley Modified). The update demonstrates that there are no significant new circumstances or information relevant to environmental concerns associated with these three rail corridors, and that they do not warrant further consideration in the Rail Alignment EIS. The Caliente-Chalk Mountain rail corridor, which also was included in the Yucca Mountain FEIS, would intersect the Nevada Test and Training Range, and was eliminated from further consideration because of U.S. Air Force concerns that a rail line within the Caliente-Chalk Mountain corridor would interfere with military readiness testing and training activities.

The Rail Alignment EIS tiers from the broader corridor analysis in both the Yucca Mountain FEIS and the Nevada Rail Corridor SEIS, consistent with the Council on Environmental Quality regulations (see 40 Code of Federal Regulations 1508.28). Under the Proposed Action considered in the Rail Alignment EIS, DOE analyzes specific potential impacts of constructing and operating a rail line along common segments and alternative segments within the Caliente and Mina corridors for the purpose of determining an alignment in which to construct and operate a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to a geologic repository at Yucca Mountain.

The Repository SEIS includes the potential environmental impacts of national transportation, and the potential impacts from the construction and operation of a rail line along specific alignments in either the Caliente or the Mina corridor, as described in the Rail Alignment EIS to ensure that the Repository SEIS considers the full scope of potential environmental impacts associated with the proposed construction and operation of the repository. Conversely, the Rail Alignment EIS includes the potential impacts of constructing and operating the repository as a reasonably foreseeable future action in its cumulative impacts analysis. To ensure consistency, the Repository SEIS, and the Nevada Rail Corridor SEIS and Rail Alignment EIS use the same inventory of spent nuclear fuel and high-level radioactive waste and the same number of rail shipments for analysis. Thus, the associated occupational and public health and safety impacts within the Nevada rail corridors under consideration are the same in both documents. Furthermore, to promote conformity, where appropriate, consistent analytical approaches were used in both documents to evaluate the various resource areas.

Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS-0250F)

Proposed Action:

- DOE would construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain.
- Repository operations would include transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain nationally and in Nevada by either mostly rail or mostly truck

Record of Decision

- Mostly rail nationally and in Nevada
- Caliente rail corridor to determine alignment

Repository SEIS
(DOE/EIS-0250F-S1)

1. Supplements the Yucca Mountain FEIS in its entirety, as modified by:
   - Record of Decision (mostly rail, Caliente corridor) (69 FR 18557)
   - Outcome of the Nevada Rail Corridor SEIS (Mina corridor)
2. Otherwise Proposed Action remains unchanged:
   - DOE would construct, operate and monitor, and eventually close a repository
   - During repository operations, shipments would occur by mostly rail
   - In Nevada, rail shipments would occur on a railroad to be constructed along an alignment within either Caliente or Mina corridors
   - Shipments also would arrive at repository by truck
3. To supplement Nevada transportation analysis, Repository SEIS will incorporate by reference relevant information from the Rail Alignment EIS:
   - Affected environments of Caliente and Mina rail alignments
   - Environmental impacts from constructing and operating a railroad along Caliente or Mina alignment
   - Cumulative impacts associated with Caliente and Mina alignments

Nevada Rail Corridor SEIS (Part 1)
(DOE/EIS-0250F-S2)

1. Supplements the Nevada transportation analysis of Yucca Mountain FEIS, as modified by:
   - Record of Decision (mostly rail) (69 FR 18557)
   - Proposed consideration of Mina corridor
2. Under the Proposed Action, DOE would construct and operate a railroad to connect the Yucca Mountain repository to an existing rail line near Wabuska, Nevada (the Mina corridor)
   - Mina corridor information and analyses to be at level of detail commensurate with that of the other corridors in the Yucca Mountain FEIS
3. Consider other corridors in Yucca Mountain FEIS for significant new circumstances or information relevant to the environmental concerns
   - Review environmental information available since Yucca Mountain FEIS
4. Conclusion:
   - Whether the Mina corridor warrants further detailed study to determine an alignment based on impact analysis
   - Whether there are significant changes or new information relevant to environmental concerns for the other corridors that would warrant further detailed study to determine an alignment

Rail Alignment EIS (Part 2)
(DOE/EIS-0369)

1. The Rail Alignment EIS tiers from the Yucca Mountain FEIS and Nevada Rail Corridor SEIS
2. Proposed Action based on Record of Decision (69 FR 18557)
   - Under Proposed Action, DOE would determine an alignment for the construction and operation of a railroad
     - ⇒ Caliente Implementing Alternative (preferred)
     - ⇒ Mina Implementing Alternative (nonpreferred)

Foreword Figure 1. Relationship among the Repository SEIS, and the Nevada Rail Corridor SEIS and Rail Alignment EIS.

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Purpose and Need for Agency Action

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1. PURPOSE AND NEED FOR AGENCY ACTION

The U.S. Department of Energy (DOE, or the Department) completed the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS) in February 2002. Since the completion of the FEIS, DOE has continued to develop the repository design and associated plans. DOE has prepared this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) to assist the U.S. Nuclear Regulatory Commission (NRC) in adopting, to the extent practicable, any environmental impact statement (EIS) prepared pursuant to Section 114(f)(4) of the *Nuclear Waste Policy Act*, as amended (NWPA, 42 U.S.C. 10101 et seq.).

Spent nuclear fuel and *high-level radioactive waste* are long-lived, highly *radioactive* materials that result from certain nuclear activities. For more than 60 years, these materials have accumulated at commercial power plants and DOE facilities and continue to accumulate across the United States. Because of their nature, spent nuclear fuel and high-level radioactive waste must be isolated from the human *environment*, and monitored for long periods. The United States has focused a national effort on the siting and development of a *geologic repository* for *disposal* of these materials and on the development of systems for transportation of the materials safely from their present storage locations to the *repository*.

Through the passage of the NWPA, Congress found that:

- The Federal Government has the responsibility to provide for the permanent disposal of high-level radioactive waste and spent nuclear fuel to protect the public health and safety and the environment.

- Appropriate precautions must be taken to ensure that these materials do not adversely affect the public health and safety and the environment for this or future generations.

Pursuant to the NWPA, Congress directed that DOE evaluate the *Yucca Mountain site* in southern Nevada as a potential location for a *monitored geologic repository*. In addition, in 2002, Congress designated the Yucca Mountain site for the development of a repository for the disposal of high-level radioactive waste and spent nuclear fuel (Public Law 107-200; 116 Stat. 735).

A *geologic* repository for spent nuclear fuel and high-level radioactive waste would permanently isolate radioactive materials in a deep *subsurface* location to limit *risk* to the health and safety of the public. This Repository SEIS addresses actions that DOE proposes to take to construct, operate and monitor, and eventually close a repository at Yucca Mountain, and to transport spent nuclear fuel and high-level radioactive waste from 76 sites to the Yucca Mountain site for disposal. Figure 1-1 shows the 72 commercial nuclear power sites and 4 DOE sites in 34 states that currently store radioactive materials that DOE would ship to the repository.[1]

[1] Spent nuclear fuel and high-level radioactive waste currently are stored at 121 sites in 39 states. However, this Repository SEIS addresses the 76 sites from which DOE would ship radioactive materials to Yucca Mountain. The balance of the sites would ship their materials to one of the DOE sites included in this Repository SEIS in accordance with DOE's Record of Decision published on June 1, 1995 (60 FR 28680) before the Department shipped them to the repository.

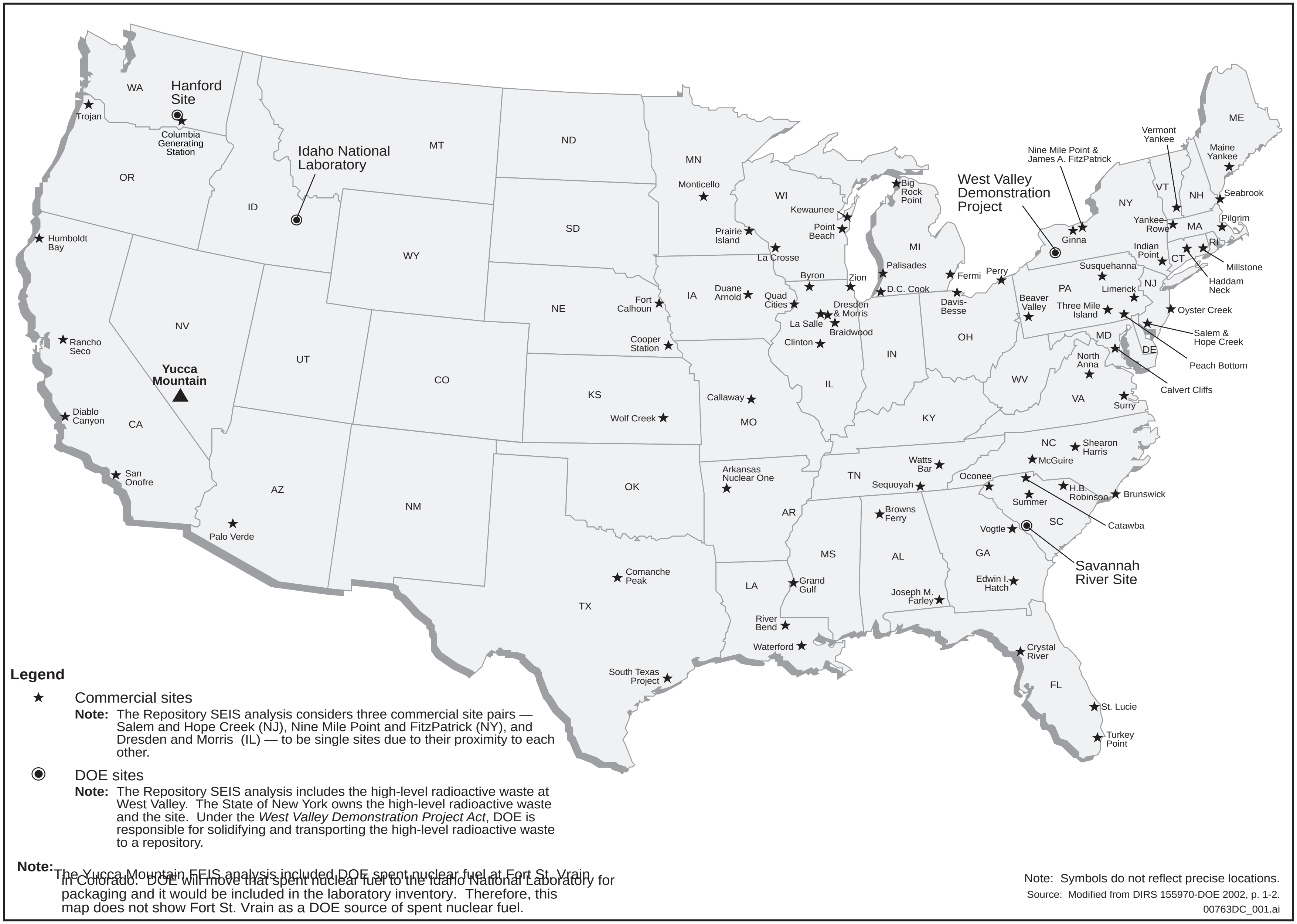

Figure 1-1. Commercial and DOE sites from which DOE would ship radioactive materials to Yucca Mountain.

Based on its obligations under the NWPA and its decision to select the mostly rail scenario for the transportation of spent nuclear fuel and high-level radioactive waste (69 FR 18557, April 8, 2004), DOE needs to ship the majority of spent nuclear fuel and high-level radioactive waste by rail to the Yucca Mountain site in Nevada. Because there is no rail access to the Yucca Mountain site, to implement its decision DOE also needs to construct and operate a *railroad* to connect the repository to an existing rail line in Nevada.

Section 1.1 provides background information related to this Repository SEIS. Section 1.2 describes important documents and actions related to Yucca Mountain. Section 1.3 provides a brief overview of spent nuclear fuel, high-level radioactive waste, and surplus weapons-usable plutonium. Section 1.4 provides an overview of the Yucca Mountain site and the proposed disposal approach. Section 1.5 presents information on the environmental *impact* analysis process as it applies to the *Proposed Action*.

1.1 Background

DOE completed the Yucca Mountain FEIS in February 2002. The Proposed Action addressed in the FEIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste.

The Yucca Mountain FEIS considered the potential environmental impacts of a repository design for surface and subsurface facilities; a range of *canister* packaging scenarios, repository thermal operating modes, and repository sizes; and plans for the *construction*, *operation*, *monitoring*, and eventual *closure* of the repository. In addition, the FEIS examined various national transportation scenarios and Nevada transportation *alternatives* for *shipment* of spent nuclear fuel and high-level radioactive waste to the repository. DOE evaluated two national transportation scenarios, referred to as the “mostly legal-weight truck scenario” and the “mostly rail scenario,” and three Nevada transportation alternatives, including shipment by legal-weight truck, rail, and *heavy-haul truck*. In the FEIS, DOE identified the mostly rail scenario as its preferred mode of transportation, both nationally and in Nevada, due in part to public preference and somewhat lower potential impacts on the health and safety of workers and the public (DIRS 155970-DOE 2002, p. 1-3).

The Yucca Mountain FEIS acknowledged that these repository design concepts and operational plans would continue to evolve during the design and engineering process and that determination of a specific *rail alignment* in which to construct a rail line would require further analysis under the *National Environmental Policy Act*, as amended (NEPA; 42 U.S.C. 6901 et seq.).

Since completion of the Yucca Mountain FEIS in 2002, DOE has continued to develop the repository design and associated construction and operational plans. As now proposed, the newly designed surface and subsurface facilities would allow DOE to operate the repository following a *primarily canistered approach* in which most commercial spent nuclear fuel would be packaged at the *reactor* sites in *transportation, aging, and disposal (TAD) canisters*. Any commercial spent nuclear fuel arriving at the repository in packages other than TAD canisters would be repackaged by DOE at the repository into TAD canisters. DOE would construct the surface and subsurface facilities over a period of several years (referred to as phased construction) to accommodate an increase in spent nuclear fuel and high-level radioactive waste receipt rates as repository operational capability reaches its design capacity. This Repository SEIS evaluates potential environmental impacts of the current repository design and operational plans to assist the NRC in the adoption, to the extent practicable, of any EIS prepared pursuant to Section 114(f)(4) of the NWPA.

1.2 Site Recommendation and Update of Yucca Mountain Decisions

On February 14, 2002, after more than two decades of scientific investigations, the Secretary of Energy submitted a comprehensive statement to the President of the United States that recommended Yucca Mountain as the site for development of a geologic repository. The Yucca Mountain FEIS accompanied the site recommendation.

On February 15, 2002, in accordance with the NWPA, the President recommended the Yucca Mountain site to Congress. On April 8, 2002, the Governor of Nevada submitted to Congress a notice of disapproval of the Yucca Mountain site designation. On May 8 and July 9, 2002, the House of Representatives and the Senate, respectively, passed a joint resolution that overrode the notice of disapproval and approved the development of a repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. On July 23, 2002, the President signed into law the joint resolution of the House of Representatives and the Senate that designated the Yucca Mountain site for development as a geologic repository (*Yucca Mountain Development Act of 2002*, Public Law 107-200; 116 Stat. 735). On October 25, 2002, following DOE's distribution of the Yucca Mountain FEIS, the U.S. Environmental Protection Agency (EPA) published its Notice of Availability of the Yucca Mountain FEIS (67 FR 65564).

On December 29, 2003, DOE published a "Notice of Preferred Nevada Rail Corridor" (68 FR 74951), that named the Caliente Corridor as its preferred *corridor* in which to construct a rail line in Nevada.

On April 8, 2004, DOE published a "Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV" (69 FR 18557), that announced the selection of the mostly rail scenario that was analyzed in the Yucca Mountain FEIS for transportation of spent nuclear fuel and high-level radioactive waste nationally and in Nevada. DOE based its decision to select the mostly rail scenario on analyses in the Yucca Mountain FEIS (specifically those analyses related to impacts on the health and safety of workers and the public), preferences expressed by the State of Nevada, consideration of irreversible and irretrievable commitments of resources, and *cumulative impacts* from transportation of other radioactive materials. Also on April 8, 2004, DOE announced it had selected the Caliente Corridor from several corridors the Department considered in the Yucca Mountain FEIS as the corridor in which to study possible rail alignments for the construction and operation of a rail line in Nevada (69 FR 18565). The Department based this decision primarily on the analyses in the Yucca Mountain FEIS, which included land-use conflicts and their potential to adversely affect the timely construction of a proposed rail line.

In 2006, DOE proposed a new approach to repository design, development, and operation. Central to this proposed approach is the use of a canister concept for commercial spent nuclear fuel that minimizes handling of individual spent fuel assemblies; limits the need for complex surface facilities; and simplifies repository design, licensing, construction, and operation. DOE would use a TAD canister to transport, age, and dispose of commercial spent nuclear fuel without ever reopening the canister, thereby simplifying and reducing the number of handling operations involved in the packaging of spent nuclear fuel for disposal. In addition, the canistered approach offers the advantage of the use of practices that are familiar to the nuclear industry and the NRC, which would make the repository easier to design, license, construct, and operate. Although DOE has a small amount of spent nuclear fuel of commercial origin that it could ship to the repository uncanistered in a cask, consistent with the analysis in the Yucca Mountain FEIS, this Repository SEIS assumes that all *DOE spent nuclear fuel* and high-level radioactive waste would be transported and received in *disposable canisters*. On October 13, 2006, in the Notice of Intent to prepare a "Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV" (71 FR 60490), DOE announced that it would prepare a supplement to the Yucca Mountain FEIS to evaluate potential environmental impacts of the current repository design and operational plans. In its Notice of Intent, DOE described the primarily canistered approach whereby most commercial sites would package their spent nuclear fuel in TAD canisters, and all DOE materials would be packaged in disposable canisters at DOE sites.

Also on October 13, 2006, DOE published an "Amended Notice of Intent to Expand the Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV" (71 FR 60484). Based on public scoping comments, discussions with the Walker River Paiute Tribe, and a preliminary evaluation of the feasibility of the Mina Corridor, DOE announced it would expand the scope of the EIS to supplement the *rail corridor* analyses of the Yucca Mountain FEIS and analyze the Mina Corridor. Although the Nevada Rail Corridor SEIS analyzes the potential environmental impacts associated with the Mina Corridor, it identifies the Mina alternative as non-preferred because the Mina Corridor would cross the Walker River Paiute Reservation, and the Tribe has withdrawn its support for the EIS process. Table 1-1 lists important documents and actions since DOE published the Yucca Mountain FEIS.

Table 1-1. Important documents and actions since DOE completed the Yucca Mountain FEIS.

Date	Document/Decision	Description
February 14, 2002	Secretary of Energy made Site Recommendation.	Secretary of Energy submitted a comprehensive statement to the President of the United States that recommended Yucca Mountain as the site for development of a geologic repository for nuclear waste. The Site Recommendation was accompanied by the Yucca Mountain FEIS.
February 15, 2002	President recommended Yucca Mountain.	President G. W. Bush recommended the Yucca Mountain site to Congress.
April 8, 2002	Nevada objected to the President's approval.	Governor of Nevada submitted a notice of disapproval of the Yucca Mountain site designation to Congress.
May 8 and July 9, 2002	House of Representatives and Senate approved Yucca Mountain.	House of Representatives and Senate, respectively, passed a joint resolution that overrode the notice of disapproval and approved the development of a repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

Table 1-1. Important documents and actions since DOE completed the Yucca Mountain FEIS (continued).

Date	Document/Decision	Description
July 23, 2002	President signed *Yucca Mountain Development Act* into law.	President G. W. Bush signed the joint resolution into law as Public Law 107-200. This law, known as the *Yucca Mountain Development Act*, was codified as 42 U.S.C. 10135 note (Supp. IV 2004). This action completed the site selection process mandated by the NWPA and allowed DOE to seek licenses from the NRC to build and operate a repository at Yucca Mountain. DOE is preparing an application for submittal to the NRC that will seek authorization to construct the repository, as required by Section 114(b) of the NWPA.
October 25, 2002	A Notice of Distribution was published (67 FR 65539) and the EPA published its Notice of Availability of the Yucca Mountain FEIS (67 FR 65564).	DOE distributed the Yucca Mountain FEIS and the EPA notified the public of its availability.
November 18, 2003	DOE published *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain*: *A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all).	This plan laid out the operational approach that DOE would follow in definition and development of the comprehensive transportation system required for the safe and secure shipment of spent nuclear fuel and high-level radioactive waste. The plan presents DOE's strategy and describes the process DOE would use to work cooperatively with states, federally recognized tribes, local governments, utilities, the transportation industry, and other interested parties.
December 29, 2003	DOE published "Notice of Preferred Nevada Rail Corridor" (68 FR 74951).	DOE named the Caliente Corridor as its preferred corridor in which to construct a rail line in Nevada.
December 29, 2003	BLM segregated public lands for up to 2 years (68 FR 74965).	BLM announced the receipt of a land withdrawal application from DOE that requested the withdrawal of approximately 1,250 square kilometers of public land in Nevada from surface entry and mining for a period of 20 years to evaluate the land for the potential construction, operation, and maintenance of a rail line for transportation of spent nuclear fuel and high-level radioactive waste in the Caliente Corridor. The notice segregated the land from surface entry and mining for as long as 2 years while DOE conducted studies and analyses to support a final decision on the withdrawal application.
April 8, 2004	DOE published "Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV" (69 FR 18557).	This Record of Decision selected the mostly rail scenario nationally and in Nevada and selected the Caliente Corridor to examine potential alignments within which to construct the rail line.

Table 1-1. Important documents and actions since DOE completed the Yucca Mountain FEIS (continued).

Date	Document/Decision	Description
April 8, 2004	DOE published "Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV" (69 FR 18565).	DOE announced it would prepare an environmental impact statement for the alignment, construction, and operation of a rail line for shipment of spent nuclear fuel, high-level radioactive waste, and other materials from a site near Caliente, Lincoln County, Nevada, to a geologic repository at Yucca Mountain, Nye County, Nevada.
July 9, 2004	U.S. Court of Appeals upheld *Yucca Mountain Development Act*.	U.S. Court of Appeals issued a decision that rejected the State of Nevada's challenge to the constitutionality of the resolution that approved Yucca Mountain. The Court denied all but one of the challenges to EPA and NRC regulations that govern Yucca Mountain. The agencies have proposed new regulations that would address compliance periods for the first 10,000 years and for post-10,000 years (up to 1 million years). The proposed regulations have not been finalized.
December 6, 2005	DOE published *Environmental Assessment for the Proposed Withdrawal of Public Lands Within and Surrounding the Caliente Rail Corridor*, *Nevada* (DIRS 176452-DOE 2005, all).	This environmental assessment evaluated the potential impacts of the proposed land withdrawal and the land evaluation activities.
December 28, 2005	BLM issued Public Land Order No. 7653 withdrawing public lands for period of 10 years (70 FR 76854).	BLM withdrew approximately 1,250 square kilometers of public lands in the Caliente Corridor in Nevada from surface entry and the location of new mining claims, subject to valid existing rights, for a period of 10 years to enable DOE to evaluate the lands for potential construction, operation, and maintenance of a rail line, which the Department would use to transport spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain repository.
October 13, 2006	DOE published "Amended Notice of Intent to Expand the Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV" (71 FR 60484).	Based on new information, DOE plans to expand the scope of the Rail Alignment EIS to incorporate an analysis of a new rail corridor alternative. The analysis will consider the potential environmental impacts of a newly proposed Mina Corridor to supplement the Yucca Mountain FEIS rail corridor analysis and will analyze alternative alignments in the Mina Corridor.
October 13, 2006	DOE published Notice of Intent to prepare a "Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV" (71 FR 60490).	DOE announced it would prepare this supplement to evaluate potential environmental impacts of the current repository design and operational plans.

Table 1-1. Important documents and actions since DOE completed the Yucca Mountain FEIS (continued).

Date	Document/Decision	Description
January 10, 2007	BLM segregated public lands for as long as 2 years (72 FR 1235).	BLM announced the receipt of a land withdrawal application from DOE requesting the withdrawal of approximately 850 square kilometers of public land in Nevada from surface entry and mining until December 27, 2015, to evaluate the land for the potential construction, operation, and maintenance of a rail line for transportation of spent nuclear fuel and high-level radioactive waste in the Caliente or Mina Corridor. The notice segregated the land from surface entry and mining for as long as 2 years while DOE conducted studies and analyses to support a final decision on the withdrawal application.

Note: Conversion factors are on the inside back cover of this Repository SEIS.
BLM = Bureau of Land Management.
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
NRC = U.S. Nuclear Regulatory Commission.
NWPA = *Nuclear Waste Policy Act*, as amended.

1.3 Radioactive Materials Considered for Disposal

This section summarizes and incorporates by reference Section 1.2 and Appendix A of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp.1-4 to 1-8 and A-1 to A-71).

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

The material used to power commercial *nuclear reactors* typically consists of cylindrical fuel pellets made of a radioactive material, uranium oxide, slightly enriched in uranium-235. Fuel pellets are placed in tubes (called "*cladding*"). The sealed tubes with fuel pellets inside are called "fuel rods." Fuel rods are arranged in bundles called "fuel assemblies," which are placed in a reactor.

After a period of operation in a reactor, the fuel is considered to be "spent." Nuclear reactor operators initially store spent nuclear fuel underwater in pools because of the high levels of *radioactivity* and heat from *decay* of *radionuclides*. When the fuel has cooled and decayed sufficiently, operators can use two storage options: (1) continued in-pool storage or (2) above-ground *dry storage*.

Beginning in 1944, the United States operated reactors to produce materials such as plutonium for nuclear weapons. After discharge of the spent nuclear fuel and other reactor-irradiated nuclear materials, DOE used a chemical *process* called "reprocessing" to extract plutonium and other materials for defense purposes from the reactor-irradiated nuclear materials, which included spent nuclear fuel. One of the chemical byproducts of reprocessing is high-level radioactive waste. In addition, the reprocessing of naval reactor fuels and some commercial reactor fuels, DOE test reactor fuels, and university and other research reactor fuels has produced high-level radioactive waste. As a result of the shutdown of weapons production and some DOE chemical reprocessing plants at the end of the Cold War, DOE did not reprocess all of its spent nuclear fuel. The Department stores some of this fuel at DOE sites, awaiting permanent disposal.

1.3.2 SPENT NUCLEAR FUEL

Spent nuclear fuel consists of nuclear fuel that has been withdrawn from a nuclear reactor, provided the constituent elements of the fuel have not been separated by reprocessing. Spent nuclear fuel is stored at commercial and DOE sites.

1.3.2.1 Commercial Spent Nuclear Fuel

Commercial spent nuclear fuel comes from nuclear reactors that produce electric power. It typically consists of uranium oxide fuel (which contains *actinides*, *fission* products, and other materials), the cladding that contains the fuel, and the assembly hardware. The cladding for commercial spent nuclear fuel assemblies is normally made of a *zirconium alloy*. Commercial spent nuclear fuel is generated and stored at commercial nuclear power plants throughout the United States. Figure 1-1 shows the locations of these sites.

1.3.2.2 DOE Spent Nuclear Fuel

DOE manages spent nuclear fuel from its defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as fuel from university and other research reactors, commercial reactor fuel acquired by DOE for research and development, and fuel from foreign research reactors. DOE stores most of its spent nuclear fuel in pools or dry storage facilities at three primary locations: the Hanford Site in Washington State, the Idaho National Laboratory in Idaho (formerly the Idaho National Engineering and Environmental Laboratory), and the Savannah River Site in South Carolina. Some DOE spent nuclear fuel is stored at the Fort St. Vrain dry storage facility in Colorado. In accordance with DOE's Record of Decision published on June 1, 1995 (60 FR 28680), the Department will transfer the fuel at Fort St. Vrain from Colorado to the Idaho National Laboratory before its shipment to the repository. The Department would transport all DOE spent nuclear fuel evaluated in this Repository SEIS to the Yucca Mountain site from the Hanford Site, Idaho National Laboratory, or Savannah River Site.

1.3.3 HIGH-LEVEL RADIOACTIVE WASTE

DOE stores high-level radioactive waste in underground tanks at the Hanford Site, the Savannah River Site, and the Idaho National Laboratory (Figure 1-1). High-level radioactive waste can be in a liquid, sludge, saltcake, solid immobilized glass, or solid granular form (calcine). It can include immobilized plutonium waste and other highly radioactive materials that the NRC has determined by rule to require permanent *isolation*.

The DOE process for preparation of high-level radioactive waste for disposal starts with the transfer of the radioactive waste from storage tanks to a treatment facility. Treatment can include separation of the waste into high- and low-activity fractions, followed by *vitrification* of the high-activity fraction. Vitrification involves the addition of inert materials to the radioactive waste and heating of the mixture until it melts. DOE pours the melted mixture into canisters, where it cools into a solid glass or ceramic form that is very resistant to the leaching of radionuclides. The solidified, immobilized glass and ceramic forms keep the waste stable, confined, and isolated from the environment. DOE will store the solidified high-level radioactive waste onsite in these canisters until eventual shipment to a repository.

DOE has completed solidification and immobilization of high-level radioactive waste at the West Valley Demonstration Project in New York, is continuing to solidify and immobilize waste at the Savannah

River Site, and plans to begin solidification and immobilization at the Hanford Site in about 2019. DOE will use the *Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement* (DIRS 179508-DOE 2002, all) to help determine the method for preparation of high-level radioactive waste at the Idaho National Laboratory for geologic disposal.

1.3.4 SURPLUS WEAPONS-USABLE PLUTONIUM

DOE has identified some weapons-usable plutonium as surplus to national security needs. This material includes purified plutonium, nuclear weapons components, and materials and residues that could be processed to produce purified plutonium. DOE currently stores these plutonium-containing materials at sites throughout the United States.

On March 28, 2007, DOE announced its intent to prepare a supplemental EIS to evaluate the potential environmental impacts of plutonium disposition alternatives (72 FR 14543). In that notice, DOE announced that it intends to analyze alternatives that could result in DOE emplacing surplus weapons-usable plutonium in the repository in two forms. One form could be vitrified plutonium waste that DOE would dispose of as high-level radioactive waste. In the Yucca Mountain FEIS, DOE analyzed the impacts of immobilizing surplus plutonium in a ceramic matrix surrounded by vitrified high-level radioactive waste. DOE is still considering this alternative. Another immobilization form DOE is considering is containment of this immobilized plutonium in a lanthanide *borosilicate glass matrix* surrounded by vitrified high-level radioactive waste for which DOE would perform analyses similar to those for immobilized ceramic plutonium it evaluated in the Yucca Mountain FEIS. A third alternative would be to fabricate mixed uranium and plutonium oxide fuel (called "mixed-oxide fuel") assemblies that would be used for power production in commercial nuclear reactors and disposed of in the same manner as other commercial spent nuclear fuel.

1.4 Yucca Mountain Site and the Proposed Disposal Approach

This section summarizes and incorporates by reference Section 1.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 1-13 to 1-22).

1.4.1 YUCCA MOUNTAIN SITE

The Yucca Mountain site is on land that is controlled by the Federal Government in a remote area of the Mojave Desert in Nye County in southern Nevada, approximately 160 kilometers (100 miles) northwest of Las Vegas, Nevada (Figure 1-2). The area surrounding the Yucca Mountain site is sparsely populated and is one of the driest regions in the United States, receiving an average of 170 millimeters (6.7 inches) of precipitation per year. Measurements of the water level in *boreholes* at Yucca Mountain indicate that the *water table* is approximately 500 to 800 meters (1,600 to 2,600 feet) below the ground surface. The repository would be above the water table in the *unsaturated zone*, the zone of soil or rock between the land surface and the water table. Chapter 3 of this Repository SEIS provides detailed information about the environment at the site.

The Yucca Mountain site has several characteristics that would limit possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. It is in a remote area on land the Federal Government controls. It is not near any highly populated area due to the extent of the *land withdrawal*

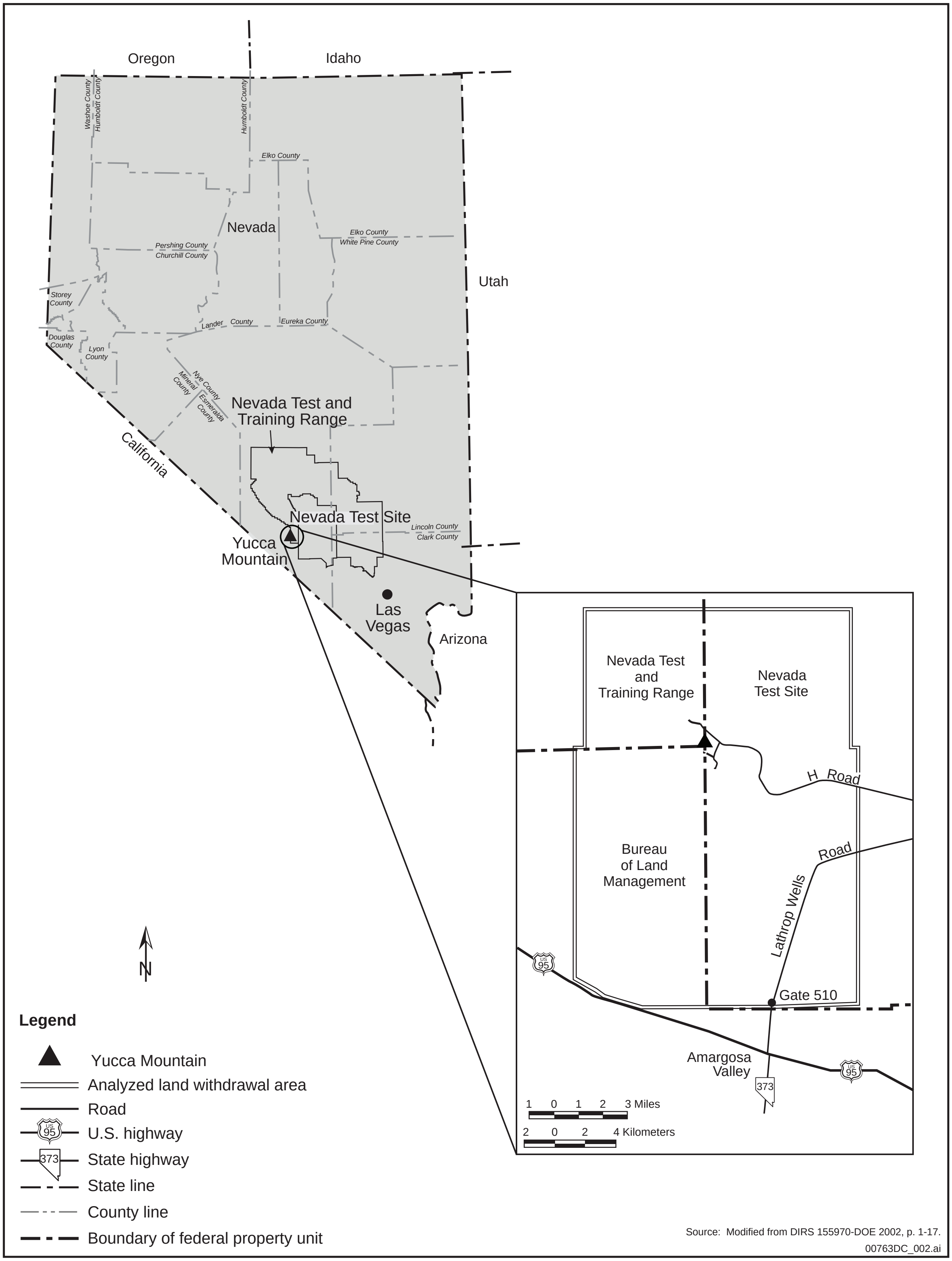

Figure 1-2. Land withdrawal area used for analytical purposes.

SITE-RELATED TERMS

Yucca Mountain site:
The area inside the site boundary over which DOE has control. For the purpose of this Repository SEIS, Yucca Mountain site is synonymous with the land withdrawal area.

Yucca Mountain site boundary:
That line beyond which DOE does not own, lease, or otherwise control the land or property for the purposes of the repository.

Land withdrawal area:
The area of federal property that DOE owns, leases, or otherwise controls for the Yucca Mountain site.

Analyzed land withdrawal area:
Because the land has not yet been withdrawn, in this Repository SEIS it is referred to as the analyzed land withdrawal area. DOE uses the same analyzed land withdrawal area for the analyses in this Repository SEIS it used in the Yucca Mountain FEIS, an area of approximately 600 square kilometers (230 square miles or 150,000 acres).

Geologic repository operations area:
As defined at 10 CFR 63.2, the geologic repository operations area is "a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted."

Region of influence (the region):
A specialized term that indicates a specific area of study for each of the resource areas that this Repository SEIS analysis addresses.

area. The dry climate results in a relatively small volume of water that can move through the unsaturated zone. The water table sits substantially below the level at which DOE would locate a repository, which provides additional separation between water sources and materials in emplaced *waste packages*. Maximizing the separation of water from the repository would minimize *corrosion* and delay any mobilization and transport of radionuclides from the repository. Chapter 5 of this Repository SEIS contains further discussion about long-term impacts.

Groundwater beneath Yucca Mountain flows into a closed, sparsely populated hydrogeologic basin. A closed basin is one in which water introduced into the basin by precipitation cannot flow out of the basin to any river or ocean. This closed basin would provide a *natural barrier* to a general spread of radionuclides if radioactive *contamination* were to reach the groundwater. The land withdrawal area analyzed in this Repository SEIS includes about 600 square kilometers (150,000 acres) of land currently under the control of DOE (Nevada Test Site), the U.S. Air Force (Nevada Test and Training Range), and the U.S. Department of the Interior (Bureau of Land Management) (Figure 1-2). Chapter 3, Section 3.1.1 of this Repository SEIS provides more detail on the land use and ownership of the land withdrawal area.

DOE would disturb approximately 12 square kilometers (3,000 acres) of the land withdrawal area to develop surface repository and rail facilities, with the remainder serving as a buffer zone. Before receipt of construction authorization, land would have to be withdrawn permanently from public access to satisfy NRC licensing requirements in 10 CFR 63.121. In addition, the Proposed Action would disturb approximately 0.57 square kilometer (140 acres) of land for an access road and offsite *infrastructure*, and approximately 39 to 58 square kilometers (9,600 to 14,000 acres) for the rail line and rail facilities outside the analyzed land withdrawal area dependent on the corridor and the alignment within the corridor.

1.4.2 PROPOSED APPROACH TO DISPOSAL

Since completion of the Yucca Mountain FEIS in 2002, DOE has continued to develop the repository design and associated construction and operational plans. As now proposed, DOE would use a primarily canistered approach to operate the repository; under this approach, most commercial spent nuclear fuel would be packaged at the reactor sites in TAD canisters. DOE would repackage commercial spent nuclear fuel that arrived in packages other than TAD canisters into these canisters in newly designed surface facilities at the repository. The Department would package essentially all DOE material in disposable canisters at the DOE sites. Most spent nuclear fuel and high-level radioactive waste would arrive at the repository by rail. Some shipments would arrive by truck. At the repository, DOE would place the TAD and other disposable canisters in waste packages that were manufactured from corrosion-resistant materials. DOE would array the waste packages in the *subsurface facility* in tunnels (emplacement *drifts*). Chapter 2 of this Repository SEIS further describes the disposal approach, which includes the transportation activities necessary to move the spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site.

The NWPA limits the amount of spent nuclear fuel and high-level radioactive waste that DOE can emplace in the first geologic repository to 70,000 *metric tons of heavy metal* (MTHM) until a second repository is in operation [NWPA, Section 114(d)]. The materials that would be disposed of under the Proposed Action include about 63,000 MTHM of commercial spent nuclear fuel and high-level radioactive waste, about 2,333 MTHM of DOE spent nuclear fuel, and about 4,667 MTHM of high-level radioactive waste. Although the NWPA limits the repository size to 70,000 MTHM, DOE considers a larger repository in the cumulative impacts section of this Repository SEIS.

1.5 Environmental Impact Analysis Process

The following information supplements the activities described in Section 1.5 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 1-25 to 1-31).

1.5.1 YUCCA MOUNTAIN FEIS

DOE completed the Yucca Mountain FEIS in February 2002 and submitted the document to the President as part of the Department's comprehensive statement that recommended Yucca Mountain as the site for development of a geologic repository. A Notice of Distribution was published in the *Federal Register* on October 25, 2002 (67 FR 65539) after DOE distributed the Yucca Mountain FEIS to the public and filed it with EPA. EPA published its Notice of Availability of the Yucca Mountain FEIS on the same day (67 FR 65564). DOE made the document available in reading rooms throughout the country and made an electronic copy available on the Internet. The Department distributed paper copies of the Readers Guide, Summary, and an errata sheet, as well as an electronic version on compact disk of the Yucca Mountain FEIS (Volumes I, II, and III) to members of Congress; federal, state, and Indian tribal governments; local officials, persons, agencies, and organizations that commented on the Draft EIS and Supplement to the Draft EIS (issued on May 11, 2001, and incorporated into the Yucca Mountain FEIS to present the latest design information and the expected environmental impacts that could result from the evolved design); and others who had indicated an interest in the EIS process.

1.5.2 NOTICES OF INTENT AND SCOPING MEETINGS

NEPA regulations do not require public scoping for the preparation of a supplemental EIS. However, on October 13, 2006, DOE published a Notice of Intent to prepare this Repository SEIS (71 FR 60490) and invited comments on the scope of the document to ensure that the document addressed all relevant environmental issues. DOE announced a 45-day public comment period that ended on November 27, 2006, and public scoping meetings in Washington, D.C., and the town of Amargosa Valley and Las Vegas, Nevada. On November 9, 2006, based on input from the public, DOE extended the public comment period to December 12, 2006, and announced an additional public scoping meeting in Reno, Nevada (71 FR 65786). During the scoping period, DOE also conducted scoping on the Rail Alignment EIS. Because public scoping occurred during the same period for both EISs, DOE received many comment documents that contained comments on both EISs. As a consequence, DOE reviewed all scoping documents, regardless of whether the document addressed the Rail Alignment EIS or this Repository SEIS, for applicability to both EISs. This ensured a full and complete consideration of all public input to the scoping process. Section 1.5.3 addresses the relationship between the two documents.

1.5.2.1 Repository SEIS

DOE considered all comments it received as a result of the scoping process and grouped them into categories, as it reported in the *Summary of Public Scoping Comments Related to the Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DIRS 179543-DOE 2007, all). The Department received 263 comment documents that resulted in 723 comments applicable to this Repository SEIS.

DOE evaluated and considered all comments. Most of the comments were not applicable to the scope of this Repository SEIS. These nonapplicable comments fell into four general categories:

1. Comments complimentary or critical of the process;

2. Comments in favor of or opposed to the repository or nuclear power;

3. Comments on items outside the scope of this Repository SEIS, such as alternatives to the repository (for example, reprocessing or interim storage), alternative locations, and need for a citizens' advisory board; and

4. Comments that were general in nature or already were part of the planned scope, analyses, and technical approaches, such as evaluation of impacts to workers and members of the public from any *exposure* to radiological or hazardous substances and consideration of groundwater impacts.

Some comments that DOE received during scoping resulted in changes to the scope or analyses. The following items summarize comments that resulted in modifications to the scope and analyses originally planned for this Repository SEIS and DOE's responses to these comments:

- DOE should present a range of TAD canister implementation scenarios and not rely solely on the 90-percent program goal (90 percent of commercial spent nuclear fuel would be placed in TAD canisters before shipment to the repository for disposal) because of uncertainties associated with implementation at each reactor site and because more than 10 percent of the spent nuclear fuel might already be packaged in *dual-purpose canisters*.

Response: This Repository SEIS addresses potential impacts of the goal of a 90-percent TAD canister scenario. To provide a perspective of any implementation differences, Appendix A discusses the impacts associated with a variation of the TAD canister implementation ratio of 75 percent.

- DOE should consider the decision of a United Nations committee in support of the Western Shoshone Tribe against the United States Government since the issuance of the Yucca Mountain FEIS.

  Response: DOE has updated the land use and ownership discussion in Chapter 3, Section 3.1.1 of this Repository SEIS to reflect the most recent information on the Western Shoshone Tribe and the Ruby Valley Treaty of 1863 and included the American Indian view associated with the new information.

- Uncertainties associated with worker residency warrant new analytical assumptions for the socioeconomics analyses.

  Response: The socioeconomics analysis for this Repository SEIS used the same relative workforce residence location that DOE used in the Yucca Mountain FEIS, which was 80 percent in Clark County and 20 percent in Nye County. This approach is based on historical data on the residency of workers on the Nevada Test Site or the Yucca Mountain site. To provide a perspective of potential differences in impacts if a larger percentage of the workforce chose to reside in Nye County, Appendix A discusses the impacts associated with a sensitivity case that assumed 20 percent of the workforce would reside in Clark County and 80 percent would reside in Nye County.

1.5.2.2 Rail Alignment EIS

DOE held two public scoping periods for the Rail Alignment EIS between April 8 and June 1, 2004, and October 13 and December 12, 2006. On April 8, 2004, DOE published a Notice of Intent (69 FR 18565) that announced it would prepare an EIS for the alignment, construction, and operation of a railroad for shipment of spent nuclear fuel, high-level radioactive waste, and other materials from a site near Caliente, Lincoln County, Nevada, to a geologic repository at Yucca Mountain, Nye County, Nevada (Rail Alignment EIS). The Notice of Intent also announced the schedule for public scoping meetings, and invited and encouraged comments on the scope of that EIS to ensure that the document addressed all relevant environmental issues and reasonable alternatives. The scoping comment period began with publication of the Notice of Intent in the *Federal Register*. The schedule called for the period to close on May 24, 2004; however, on April 26, 2004, based on a request from the State of Nevada, DOE extended the comment period to June 1, 2004 (69 FR 22496).

DOE received more than 4,100 comments during the first public scoping period for the Rail Alignment EIS and some comments after the close of the scoping period. DOE summarized all these comments in the *Summary of Public Scoping Comments, Related to the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV* (DIRS 176463-Craig et al. 2004, all) and considered the content of all comments in its determination of the scope of the EIS. The following are the general modifications to the scope and analyses originally planned for the Rail Alignment EIS:

- The elimination, addition, or modification of rail segment alternatives;
- The addition of a Shared-Use option that considers commercial use of the proposed rail line; and
- Additional fieldwork in Garden Valley for the noise and aesthetics analyses.

On October 13, 2006, DOE published an Amended Notice of Intent (71 FR 60484) that announced the expanded scope of the Rail Alignment EIS to include detailed analysis of construction and operation of a railroad in the Mina Corridor, should that corridor warrant further consideration based on the analysis of the Nevada Rail Corridor SEIS. The Notice of Intent also announced the schedule for public scoping meetings, and encouraged comments on the scope of the EIS to ensure that the document addressed all relevant environmental issues and reasonable alternatives. The second scoping comment period began with publication of the Amended Notice of Intent in the *Federal Register* and was originally scheduled to close on November 27, 2006. On November 9, 2006, based on requests from the public, DOE extended the comment period to December 12, 2006 (71 FR 65785).

DOE received nearly 800 comments during the second public scoping period for the Rail Alignment EIS, including some comments after the close of the scoping period. DOE summarized all comments received (including those submitted after the close of the scoping period) in *Summary of Public Scoping Comments on the Expanded Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV* (DIRS 181379-DOE 2007, all) and considered the content of all comments in its determination of the scope of the EIS. Most of the comments that DOE received in the second public scoping period were similar to those received in the first period.

Chapter 1 of the Rail Alignment EIS contains additional information on the evaluation and assessment of comments received during both scoping periods about the Caliente and Mina rail alignments. Chapter 1 of the Nevada Rail Corridor SEIS contains additional information on the evaluation and assessment of comments that DOE received during the second scoping period about the Mina Corridor and the update of information related to the other corridors DOE analyzed in the Yucca Mountain FEIS.

1.5.3 RELATIONSHIP TO OTHER ENVIRONMENTAL DOCUMENTS

A number of completed, in preparation, or proposed DOE NEPA documents relate to this Repository SEIS. In addition, other federal agencies have prepared related EISs. Consistent with Council on Environmental Quality regulations that implement NEPA (40 CFR Parts 1500 to 1508), DOE has used information from these documents in its analyses and has incorporated this material by reference as appropriate throughout this Repository SEIS.

As discussed above, DOE is preparing the Nevada Rail Corridor SEIS and Rail Alignment EIS, which supplement the Nevada transportation information in the Yucca Mountain FEIS and are, therefore, incorporated by reference throughout this Repository SEIS, as appropriate. The Nevada Rail Corridor SEIS supplements the rail corridor analysis of the Yucca Mountain FEIS by analyzing the potential environmental impacts associated with constructing and operating a railroad within the Mina Corridor. The Nevada Rail Corridor SEIS analyzes the Mina Corridor at a level of detail commensurate with that of the rail corridor analysis in the Yucca Mountain FEIS, and concludes that the Mina Corridor warrants further study in the Rail Alignment EIS to identify an alignment for the construction and operation of a railroad. The Nevada Rail Corridor SEIS also updates relevant information regarding three other rail corridors previously analyzed in the Yucca Mountain FEIS (Carlin, Jean, and Valley Modified). The update demonstrates that there are no significant new circumstances or information relevant to environmental concerns associated with these three rail corridors, and that they do not warrant further consideration in the Rail Alignment EIS. The Caliente-Chalk Mountain rail corridor, which also was included in the Yucca Mountain FEIS, would intersect the Nevada Test and Training Range, and was eliminated from further consideration because of U.S. Air Force concerns that a rail line within the Caliente-Chalk Mountain corridor would interfere with military readiness testing and training activities.

The Rail Alignment EIS tiers from the broader corridor analysis in both the Yucca Mountain FEIS and the Nevada Rail Corridor SEIS, consistent with the Council on Environmental Quality regulations (40 CFR 1508.28). Under the Proposed Action considered in the Rail Alignment EIS, DOE would determine a rail alignment within the Caliente or Mina Corridor and would construct, operate, and potentially abandon a railroad for the shipment of spent nuclear fuel, high-level radioactive waste, and other materials from an existing railroad in Nevada to a geologic repository at Yucca Mountain.

In all relevant aspects, this Repository SEIS, the Nevada Rail Corridor SEIS, and the Rail Alignment EIS are consistent (Foreword, Figure 1). For example, the Repository SEIS and the Rail Alignment EIS use the same inventory of spent nuclear fuel and high-level radioactive waste, so the number of rail shipments and associated occupational and public health and safety impacts in Nevada are the same in both documents. Where appropriate, the approaches used to analyze the resource areas are consistent. Further, this Repository SEIS, which supplements the Yucca Mountain FEIS, including its Nevada mostly rail element, incorporates by reference the impact evaluations of the Rail Alignment EIS. Conversely, the Rail Alignment EIS considers the impacts from construction of the repository in its cumulative impacts analysis.

In June 2006, DOE published the *Draft Environmental Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada* (DIRS 178817-DOE 2006, all). In October 2006, the Department decided to prepare this Repository SEIS and will not be finalizing the environmental assessment but has incorporated the elements of infrastructure improvements into the Repository SEIS Proposed Action. The proposed action in the environmental assessment was to repair, replace, or improve certain facilities, structures, roads, and utilities for the Yucca Mountain Project to enhance safety at the project and to enable DOE to safely continue ongoing operations, scientific testing, and routine *maintenance* at the *Exploratory Studies Facility* until such time as the NRC decides whether to authorize construction of a repository. Chapter 4 of this Repository SEIS identifies the specific elements, or subelements, of those improvements that DOE could implement before receiving a construction authorization from the NRC. Before implementation, a Record of Decision on this SEIS will present any decisions DOE might make regarding the improvements. These actions would be independent of repository construction and would be conducted under DOE authority.

On July 23, 2007, DOE published a “Notice of Intent To Prepare an Environmental Impact Statement for the Disposal of Greater-Than-Class-C Low-Level Radioactive Waste” (72 FR 40135). The EIS will evaluate alternatives for disposal of wastes with a concentration greater than Class C, as defined in NRC regulations at 10 CFR Part 61, in a geologic repository, in intermediate depth boreholes, and in enhanced near-surface facilities. Candidate locations for these disposal facilities are the Idaho National Laboratory in Idaho, the Los Alamos National Laboratory and Waste Isolation Pilot Plant in New Mexico, the Nevada Test Site and the proposed *Yucca Mountain Repository* in Nevada, the Savannah River Site in South Carolina, the Oak Ridge Reservation in Tennessee, and the Hanford Site in Washington. DOE will also evaluate disposal at generic commercial facilities in arid and humid locations. In addition, DOE proposes to include DOE *low-level radioactive waste* and *transuranic waste* that have characteristics similar to Greater-Than-Class-C low-level radioactive waste and that might not have an identified path to disposal. These inventories would include the materials evaluated in the Yucca Mountain FEIS (referred to as "Special-Performance-Assessment-Required low-level radioactive wastes"). DOE issued a Notice of Intent on July 23, 2007 (72 FR 40135) to invite the public to provide comments on the potential scope of the EIS and participate in public scoping meetings. This Repository SEIS evaluates potential impacts from disposal of Greater-Than-Class-C low-level radioactive waste in Chapter 8 as reasonably foreseeable cumulative impacts.

DOE is preparing the *Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership* (DOE/EIS-0396). The Global Nuclear Energy Partnership (GNEP) would encourage expansion of domestic and international nuclear energy production while reducing nuclear proliferation risks, and reduce the volume, thermal output, and radiotoxicity of spent nuclear fuel before disposal in a geologic repository (72 FR 331, January 4, 2007). DOE anticipates that its Programmatic EIS will evaluate a range of alternatives including a proposal to recycle spent nuclear fuel and separate many of the high-heat fission products and the uranium and transuranic components. The full implementation of GNEP would involve the construction and operation of advanced reactors, which would be designed to generate energy while destroying the transuranic elements. DOE also anticipates evaluating project-specific proposals to construct and operate an advanced fuel-cycle research facility at one or more DOE sites.

The United States uses a "once-through" fuel cycle in which a nuclear power reactor uses nuclear fuel only once, and then the utility places the spent nuclear fuel in storage while awaiting disposal. GNEP would establish a fuel cycle where the uranium and transuranic materials would be separated from the spent nuclear fuel and reused in thermal and/or advanced nuclear reactors. GNEP would not diminish in any way the need for the nuclear waste disposal program at Yucca Mountain, because under any fuel recycle scenario, high-level radioactive waste will continue to be produced and require disposal.

DOE anticipates that by about 2020 the commercial utilities will have produced about 86,000 MTHM of spent nuclear fuel, which exceeds DOE's disposal limit of 63,000 MTHM of commercial spent nuclear fuel for the Yucca Mountain repository. If DOE were to decide, in a GNEP Record of Decision, to proceed with its proposal to recycle spent nuclear fuel, the Department anticipates that the necessary facilities would not commence operations until 2020 or later. Although the spent nuclear fuel-recycling concept has not yet been implemented and the capacity of a separations facility has not been determined, one or more separations facilities could be designed with a total capacity sufficient to recycle the spent nuclear fuel discharged by commercial utilities. Consequently, the Department believes there would be no change in the spent nuclear fuel and high-level radioactive waste inventory analyzed under the Proposed Action of this Repository SEIS (that is, 63,000 MTHM of commercial spent nuclear fuel, which could include about 280 canisters of commercial high-level radioactive waste from the West Valley Demonstration Project, and 7,000 MTHM of DOE spent nuclear fuel [about 3,200 canisters] and high-level radioactive waste [about 9,300 canisters]).

Overall, development of a GNEP fuel cycle has the potential to decrease the amount (number of assemblies) of spent nuclear fuel that would require geologic disposal, but could increase the number of canisters of high-level radioactive waste requiring disposal in a geologic repository in the longer term. Consequently, recycling of commercial spent nuclear fuel could affect the nature of the inventory that represents the balance of Inventory Module 1 (i.e., commercial spent nuclear fuel in amounts greater than

63,000 MTHM). Nevertheless, given the uncertainties inherent at this time in estimating the amount of spent nuclear fuel and high-level radioactive waste that would result from full or partial implementation of GNEP, this Repository SEIS analyzes the transportation and disposal of about 130,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel and about 35,780 canisters of high-level radioactive waste (Inventory Module 1). Section 8.1.2.1 provides the basis for the estimates of the inventory in Module 1.

Table 1-2 lists the documents published since DOE completed the Yucca Mountain FEIS that relate to the information and analyses in this Repository SEIS.

Table 1-2. NEPA documents and Records of Decision related to this Repository SEIS (since DOE completed the Yucca Mountain FEIS).

Document	Relationship to Repository SEIS
Nuclear materials activities	
West Valley Demonstration Project Waste Management Environmental Impact Statement Final (DIRS 179454-DOE 2003, all)	Examines impacts of shipping radioactive wastes that are either in storage or that will be generated from operations over the next 10 years at West Valley to offsite disposal locations, and to continue its ongoing onsite waste management activities.
Record of Decision, "West Valley Demonstration Project Waste Management Activities" (70 FR 35073, June 16, 2005)	Selects offsite shipment of LLW for disposal at commercial sites and storage of canisters of vitrified high-level radioactive waste at the West Valley Demonstration Project site until DOE can ship them to a geologic repository for disposal.
Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement (DIRS 179508-DOE 2002, all)	Examines impacts of treatment, storage, and disposal of INL high-level radioactive waste and facilities disposition. INL high-level radioactive waste is proposed for repository disposal.
Supplement Analysis for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement (DIRS 179524-DOE 2005, all)	Determines whether there are substantial changes in the proposed action in the *Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement* that are relevant to environmental concerns or significant new circumstances or information that would require preparation of a supplemental EIS.
"Office of Environmental Management; Record of Decision for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement" (70 FR 75165, December 19, 2005)	Announces a phased decisionmaking process, meaning DOE will issue amended Records of Decision to address specifically closure of the Tank Farm Facility and the final strategy for high-level radioactive waste calcine disposition. Addresses treatment of sodium-bearing waste using steam reforming technology and management of the waste to enable disposal at the Waste Isolation Pilot Plant near Carlsbad, New Mexico, or at a geologic repository for spent nuclear fuel and high-level radioactive waste. Addresses conduct of performance-based closure of existing facilities directly related to the High-Level Radioactive Waste Program at the Idaho Nuclear Technology and Engineering Center once its missions are complete.
Final Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah (DIRS 157761-NRC 2001, all)	Addresses the proposal of Private Fuel Storage, LLC, to construct and operate an independent spent nuclear fuel storage installation on the reservation of the Skull Valley Band of Goshute Indians.

Table 1-2. NEPA documents and Records of Decision related to this Repository SEIS (since DOE completed the Yucca Mountain FEIS) (continued).

Document	Relationship to Repository SEIS
Nuclear materials activities (continued	
"Notice of Intent To Prepare an Environmental Impact Statement for the Disposal of Greater-Than-Class-C Low-Level Radioactive Waste" (72 FR 40135, July 23, 2007)	Will evaluate alternatives for disposal of wastes with a concentration greater than Class C, as defined in NRC regulations at 10 CFR Part 61: in a geologic repository; in intermediate-depth boreholes; and in enhanced near-surface facilities. In addition, DOE proposes to include DOE LLW and transuranic waste having characteristics similar to GTCC LLW and which may not have an identified path to disposal. This Repository SEIS considers cumulative impacts from disposal of GTCC LLW.
"Notice of Intent To Prepare a Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership" (72 FR 331, January 4, 2007)	GNEP involves a proposal to recycle spent nuclear fuel and destroy the long-lived radioactive components of that spent fuel. This Repository SEIS considers cumulative impacts that could be associated with implementation of the proposed spent fuel recycling and alternatives.
Draft Environmental Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada (DIRS 178817-DOE 2006, all)	In October 2006, the Department decided to prepare this Repository SEIS. Rather than finalizing this environmental assessment, DOE has incorporated the elements of infrastructure improvements into the Repository SEIS Proposed Action. Chapter 4 of this SEIS identifies the specific elements, or subelements, of these improvements that could be implemented prior to a construction authorization from the NRC. Prior to implementation, a Record of Decision on this Repository SEIS will present any decisions DOE might make regarding the improvements. These actions would be independent of repository construction and would be conducted under DOE authority.
"Notice of Intent To Prepare a Supplemental Environmental Impact Statement for Surplus Plutonium Disposition at the Savannah River Site" (72 FR 14543, March 28, 2007)	Will analyze the potential environmental impacts of alternative disposition methods of up to about 13 metric tons of non-pit surplus plutonium. These alternatives would result in waste forms (inclusion in high-level radioactive waste canisters produced at Savannah River Site or irradiated mixed-oxide spent fuel) that could be disposed of in a geologic repository.
Regional description and cumulative impact information	
Final Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory (DIRS 162639-DOE 2002, all)	Evaluates the environmental impacts associated with relocation of the Technical Area 18 capabilities and materials (presently at Los Alamos) to each of four alternative sites, including Nevada Test Site.
"Record of Decision for the Final Environmental Impact Statement for the Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory" (67 FR 79906, December 31, 2002)	Implements the preferred alternative, which would relocate Security Category I and II missions and related materials to the Device Assembly Facility at the Nevada Test Site.

Table 1-2. NEPA documents and Records of Decision related to this Repository SEIS (since DOE completed the Yucca Mountain FEIS) (continued).

Document	Relationship to Repository SEIS
Regional description and cumulative impact information (continued)	
"Notice of Intent To Prepare a Supplement to the Stockpile Stewardship and Management Programmatic Environmental Impact Statement--Complex 2030" (71 FR 61731, October 19, 2006) (Note: This document is now referred to as the *Complex Transformation Supplemental Programmatic Environmental Impact Statement*)	Will analyze the environmental impacts from the continued transformation of the U.S. nuclear weapons complex by implementation of the National Nuclear Security Administration's vision of the complex as it would exist in 2030, which is referred to as Complex 2030, as well as reasonable alternatives. The proposed action is to continue currently planned modernization activities and select a site for a consolidated plutonium center for long-term research and development, surveillance, and pit[a] manufacturing; consolidate special nuclear materials throughout the complex; consolidate, relocate, or eliminate duplicative facilities and programs and improve operating efficiencies; identify one or more sites for conducting flight test operations; and accelerate nuclear weapons dismantlement activities.
"Notice of Intent To Prepare a Programmatic Environmental Impact Statement, Amend Relevant Agency Land Use Plans, Conduct Public Scoping Meetings, and Notice of Floodplain and Wetlands Involvement" (70 FR 56647, September 28, 2005)	Will address the environmental impacts from designation of corridors on federal land in the 11 western states for oil, gas and hydrogen pipelines and electricity transmission and distribution facilities (energy corridors), as required by Section 368 of the *Energy Policy Act of 2005* (Public Law 109-58). DOE and Bureau of Land Management will co-lead this effort, with the U.S. Department of Agriculture's Forest Service, the Department of Defense, and the Department of the Interior's Fish and Wildlife Service participating as federal cooperating agencies.
Nevada transportation activities	
"Notice of Preferred Nevada Rail Corridor" (68 FR 74951, December 29, 2003)	Announces the Caliente Corridor, from the five rail corridors studied in the Yucca Mountain FEIS, as DOE's preferred rail corridor in which to construct a rail line.
"Notice of Proposed Withdrawal and Opportunity for Public Meeting; Nevada" (68 FR 74965, December 29, 2003)	Announces the Bureau of Land Management's receipt of a request from DOE to withdraw public land from surface entry and mining for a period of 20 years to evaluate the land for the potential construction, operation, and maintenance of a rail line for the transportation of spent nuclear fuel and high-level radioactive waste in Nevada. Segregates the land from surface entry and mining for as long as 2 years while DOE conducts studies and analyses to support a final decision on the withdrawal application.
Supplement Analysis (DIRS 172285-DOE 2004, all)	Supplement to the Yucca Mountain FEIS. Examines the potential environmental impacts of shipping legal-weight truck casks on railcars from generator sites to Nevada.
"Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV" (69 FR 18557, April 8, 2004)	Selects the mostly rail scenario analyzed in the Yucca Mountain FEIS as the mode of transportation on a national basis and in the State of Nevada. Selects the Caliente Corridor for alignment, construction, and operation of a proposed rail line to Yucca Mountain.
"Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV" (69 FR 18565, April 8, 2004)	Announces DOE's intent to prepare an EIS for the alignment, construction, and operation of a rail line for the shipment of spent nuclear fuel, high-level radioactive waste, and other materials from a site near Caliente, Lincoln County, Nevada to a geologic repository at Yucca Mountain, Nye County, Nevada.

Table 1-2. NEPA documents and Records of Decision related to this Repository SEIS (since DOE completed the Yucca Mountain FEIS) (continued).

Document	Relationship to Repository SEIS
Nevada transportation activities (continued)	
Draft Resource Management Plan/ Environmental Impact Statement for the Ely District (DIRS 174518-BLM 2005, all)	Examines implementation of Bureau of Land Management resource management plans, actions, and goals in the Ely area.
Environmental Assessment for the Proposed Withdrawal of Public Lands Within and Surrounding the Caliente Rail Corridor, Nevada (DIRS 176452-DOE 2005, all)	Examines the environmental impacts of withdrawal of public lands from surface entry and new mining claims for as long as 20 years to enable evaluation of the land for the proposed rail line.
"Public Land Order No. 7653; Withdrawal of Public Lands for the Department of Energy to Protect the Caliente Rail Corridor, Nevada" (70 FR 76854, December 28, 2005)	Withdraws public lands within the Caliente Corridor from surface entry and the location of new mining claims, subject to valid existing rights, for 10 years to enable DOE to evaluate the lands for the potential construction, operation, and maintenance of a rail line.
"Amended Notice of Intent to Expand the Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV" (71 FR 60484, October 13, 2006)	Announces DOE's intent to expand the scope of the Rail Alignment EIS to incorporate an analysis of the potential environmental impacts of a newly proposed Mina Corridor.
"Notice of Proposed Withdrawal and Opportunity for Public Meeting; Nevada" (72 FR 1235, January 10, 2007)	Announces the Bureau of Land Management's receipt of an application from DOE to withdraw public lands from surface entry and mining through December 27, 2015, to evaluate the land for the potential construction, operation, and maintenance of a rail line. This covers the Mina rail alignment and segments of the Caliente rail alignment not covered in Public Land Order No. 7653. Segregates the land from surface entry and mining for as long as 2 years while DOE conducts studies and analyses to support a final decision on the withdrawal application.
Nevada Rail Corridor SEIS and Rail Alignment EIS	Examine potential impacts for the alignment, construction, and operation of a railroad in Nevada for the shipment of spent nuclear fuel, high-level radioactive waste, and other materials to a geologic repository at Yucca Mountain, Nye County, Nevada.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. A pit is the central core of a nuclear weapon, which typically contains plutonium-239 that undergoes fission when compressed by high explosives.

DOE = U.S. Department of Energy.
EIS = Environmental Impact Statement.
GNEP = Global Nuclear Energy Partnership.
GTCC = Greater-Than-Class-C.
INL = Idaho National Laboratory.
LLW = Low-level radioactive waste.
NRC = U.S. Nuclear Regulatory Commission.

1.5.4 CONFORMANCE WITH DOCUMENTATION REQUIREMENTS

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

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

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

1.5.5 COOPERATING AGENCY

Pursuant to the NWPA, DOE is responsible for the disposal of spent nuclear fuel and high-level radioactive waste to protect public health, safety, and the environment, and for development and implementation of a plan for transportation of spent nuclear fuel and high-level radioactive waste to a repository at Yucca Mountain. Therefore, DOE is the lead agency responsible for preparation of this Repository SEIS. The Council on Environmental Quality regulations emphasize agency cooperation early in the NEPA process and allow a lead agency to request the assistance of other agencies that either have jurisdiction by law or special expertise about issues considered in an EIS.

Nye County, Nevada, is the situs jurisdiction of the Yucca Mountain Repository and has special expertise on the relationship of DOE's Proposed Action to the objectives of regional and local land-use plans, policies and controls, and to the current and planned infrastructure in the county, including public services and traffic conditions. As such, Nye County is a cooperating agency in the development of this Repository SEIS, pursuant to Council on Environmental Quality regulations at 40 CFR 1501.5 and 1501.6, and has provided input (DIRS 182850-Swanson 2007, all).

Consistent with Council on Environmental Quality regulations and guidance on cooperating agencies, Nye County accepted the scope of DOE's analysis, definition, and description of the Proposed Action and alternatives, and the purpose and need for DOE's action. Participation as a cooperating agency is consistent with the stated county policy of constructive engagement with DOE (Nye County Board of Commissioners Resolution No. 2002-22) and with the objectives of the county's Community Protection Plan (approved August 2006).

Representatives from Nye County attended public, project, and technical working group meetings; participated on interdisciplinary teams; compiled and provided socioeconomic data such as population, housing, and other forecasting information; provided relevant reports and studies prepared or conducted by the county; assisted with the identification of environmental issues and with environmental analyses; reviewed working draft and preliminary draft documents; and assisted with the resolution of comments.

REFERENCES

174518 BLM 2005 BLM (Bureau of Land Management) 2005. *Draft-Resource Management Plan/Environmental Impact Statement for the Ely District*. Volume 1 (Chapters 1, 2, and 3) and Map Volume. Ely, Nevada: Bureau of Land Management, Ely Field Office. ACC: MOL.20060222.0131; MOL.20060222.0132.

176463	Craig et al. 2004	Craig, W.; Lechel, D.; and Morton, L. 2004. *Summary of Public Scoping Comments, Related to the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*. Revision 00. Augusta, Georgia: Dade Moeller & Associates. ACC: MOL.20041011.0344.
155970	DOE 2002	DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; MOL.20020524.0315; MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319; MOL.20020524.0320.
162639	DOE 2002	DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory*. DOE/EIS-0319. Volume 1. Washington, D.C.: U.S. Department of Energy, National Nuclear Security Administration. ACC: MOL.20030409.0002.
179508	DOE 2002	DOE (U.S. Department of Energy) 2002. *Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement*. DOE/EIS-0287. Washington, D.C.: U.S. Department of Energy.
172433	DOE 2003	DOE (U.S. Department of Energy) 2003. *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions*. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20041206.0113.
179454	DOE 2003	DOE (U.S. Department of Energy) 2003. *West Valley Demonstration Project Waste Management Environmental Impact Statement Final*. DOE/EIS-0337F. West Valley, New York: U.S. Department of Energy West Valley Area Office.
172285	DOE 2004	DOE (U.S. Department of Energy) 2004. *Supplement Analysis*. DOE/EIS-0250/SA-1. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20041122.0203.
176452	DOE 2005	DOE (U.S. Department of Energy) 2005. *Environmental Assessment for the Proposed Withdrawal of Public Lands Within and Surrounding the Caliente Rail Corridor, Nevada*. DOE/EA 1545, Rev. 0. Las Vegas, Nevada: Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.20060227.0001.

179524	DOE 2005	DOE (U.S. Department of Energy) 2005. *Supplement Analysis for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement*. DOE/EIS-0287-SA-01. Idaho Falls, Idaho. U.S. Department of Energy, Idaho Operations Office.
178817	DOE 2006	DOE (U.S. Department of Energy) 2006. *Draft Environmental Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada*. DOE/EA-1566. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.20060911.0011.
179543	DOE 2007	DOE (U.S. Department of Energy) 2007. *Summary of Public Scoping Comments Related to the Supplemental Yucca Mountain Repository Environmental Impact Statement*. Las Vegas, Nevada: Bechtel SAIC Company.
181379	DOE 2007	DOE (U.S. Department of Energy) 2007. *Summary of Public Scoping Comments, Expanded Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, Nevada, The Mina Corridor and Alternative Rail Alignments Within this Corridor*. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20070524.0073.
157761	NRC 2001	NRC (U.S. Nuclear Regulatory Commission) 2001. *Final Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah*. NUREG-1714. Two volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. TIC: 253836.
182850	Swanson 2007	Swanson, D. 2007. Memorandum of Understanding Between the Office of Civilian Radioactive Waste Management and Nye County, Nevada. Letter from D. Swanson (Nye County) to J. Summerson (YMSCO), April 9, 2007, 0412075994, 07-099-DS (L), with enclosure. ACC: MOL.20070430.0246; MOL.20070430.0247.

2

Proposed Action and No-Action Alternative

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2. PROPOSED ACTION AND NO-ACTION ALTERNATIVE

Under the *Proposed Action*, the U.S. Department of Energy (DOE or the Department) would construct, operate and monitor, and eventually close a *geologic repository* for the *disposal* of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain. Since publication of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS) in 2002, DOE has continued to develop the *repository* design and associated construction and operation plans. DOE has prepared this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) to evaluate the potential environmental *impacts* of the specific design, which includes plans for the repository's surface and *subsurface* facilities and transportation of spent nuclear fuel and high-level radioactive waste to the repository, that DOE will submit to the U.S. Nuclear Regulatory Commission (NRC) in its application for construction authorization for a geologic repository.

Section 2.1 discusses the Proposed Action. Section 2.2 incorporates by reference the *No-Action Alternative* presented in the Yucca Mountain FEIS, and Section 2.3 summarizes the findings of this Repository SEIS, which include the findings of the Rail Alignment EIS, and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative. Section 2.4 addresses the collection of information and the analyses that DOE performed for this Repository SEIS. Section 2.5 identifies DOE's preferred *alternative*.

2.1 Proposed Action

This introduction provides an overview of the Proposed Action and refers the reader to the sections in this Repository SEIS that contain further detail. Figure 2-1 illustrates the components or activities associated with implementation of the Proposed Action using the current design and associated plans.

Under the Proposed Action, DOE would construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of up to 70,000 *metric tons of heavy metal* (MTHM) of commercial and *DOE spent nuclear fuel* and high-level *radioactive* waste. In its simplest terms, the repository would be a large subsurface excavation with a network of *drifts*, or tunnels, that DOE would use for *emplacement* of spent nuclear fuel and high-level radioactive waste. DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the inherent, natural *geologic* features of the mountain and *engineered* (manmade) *barriers* to help ensure the long-term *isolation* of these materials from the human *environment*. The NRC, through its licensing process, would regulate repository *construction*, operation and *monitoring*, and *closure*.

Under the Proposed Action, the Department would transport most spent nuclear fuel and high-level radioactive waste from 72 commercial and 4 DOE sites to the repository in NRC-certified *transportation casks* on trains dedicated only to these *shipments*. However, DOE would transport some shipments to the repository in transportation casks by truck over the nation's highways. Naval spent nuclear fuel would be transported to the repository in transportation casks on railcars in general freight service or dedicated trains.

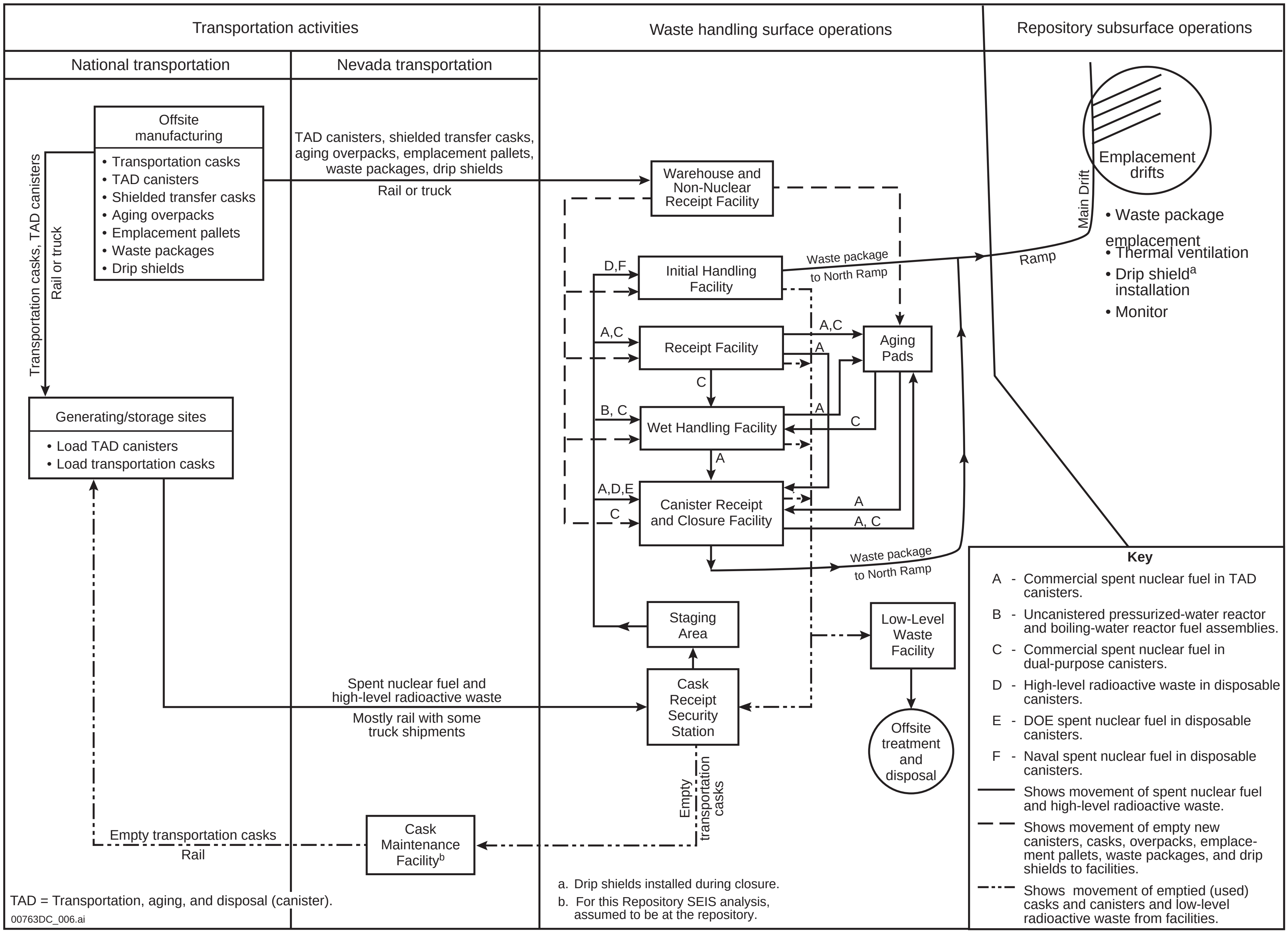


Figure 2-1. Overview flowchart for typical operations of the Proposed Action.

> **DEFINITION OF METRIC TONS OF HEAVY METAL**
>
> Quantities of spent nuclear fuel are traditionally expressed in terms of MTHM (typically uranium, but including plutonium and thorium), without the inclusion of other materials such as cladding (the tubes that contain the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 short tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel are called heavy metals because they are extremely dense; that is, they have high weights per unit volume. One MTHM disposed of as spent nuclear fuel would fill a space approximately the size of the refrigerated storage area in a typical household refrigerator.
>
> The Yucca Mountain FEIS described the equivalence methods by which MTHM is determined for high-level radioactive waste (pages A-36 to A-37). An MTHM equivalence is needed for high-level radioactive waste because its matrix is mostly silica or glass and almost all of its heavy metal has been removed. In this Repository SEIS, MTHM used in conjunction with high-level radioactive waste means MTHM equivalent, as explained in the Yucca Mountain FEIS.

High-level radioactive waste and DOE spent nuclear fuel would be placed in *disposable canisters* at the DOE sites and shipped to the repository. A small amount of DOE spent nuclear fuel of commercial origin could be shipped to the repository as *uncanistered spent nuclear fuel*. As much as 90 percent of the *commercial spent nuclear fuel* would be placed in *transportation, aging, and disposal (TAD) canisters* at the commercial sites before shipment. The remaining commercial spent nuclear fuel (about 10 percent) would be transported to the repository in *dual-purpose canisters* (*canisters* suitable for storage and transportation), or as uncanistered spent nuclear fuel. Spent nuclear fuel shipped in dual-purpose canisters or as uncanistered spent nuclear fuel would be placed in TAD canisters at the repository.

At the repository, DOE would conduct waste handling activities, discussed below, to manage thermal output of the commercial spent nuclear fuel and to package the spent nuclear fuel into TAD canisters. The disposable canisters and TAD canisters would be placed into *waste packages* for disposal in the repository. A waste package is a container that consists of the barrier materials and internal components in which DOE would place the canisters that contained spent nuclear fuel and high-level radioactive waste. Section 2.1.1 discusses fuel packaging in TAD canisters and dual-purpose canisters more fully.

DOE would place approximately 11,000 waste packages, containing no more than a total of 70,000 MTHM, of spent nuclear fuel and high-level radioactive waste in the repository at Yucca Mountain. The *Proposed Action inventory*, or materials planned for disposal at the *Yucca Mountain Repository*, includes approximately:

- 63,000 MTHM of commercial spent nuclear fuel from boiling-water and pressurized-water *reactors*, which includes commercial high-level radioactive waste from the West Valley Demonstration Project,
- 2,333 MTHM of DOE spent nuclear fuel, which includes about 65 MTHM of naval spent nuclear fuel, and
- 4,667 MTHM of DOE high-level radioactive waste.

The Yucca Mountain FEIS evaluated the *cumulative impacts* of two additional inventories (Modules 1 and 2). Modules 1 and 2 include spent nuclear fuel and high-level radioactive waste in addition to the Proposed Action inventory, as well as other radioactive wastes generally considered unsuitable for near-surface disposal. Chapter 8 of this Repository SEIS contains updated inventories for Modules 1 and 2.

The handling and disposal of spent nuclear fuel and high-level radioactive waste would take place in an area known as the *geologic repository operations area*. The geologic repository operations area is defined at 10 CFR Part 63.2, as "a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted." The surface portion of the geologic repository operations area would include the facilities necessary to receive, package, and support emplacement of spent nuclear fuel and high-level radioactive waste in the repository. The subsurface portion of the geologic repository operations area would include the facilities necessary for emplacement. Section 2.1.2 discusses the geologic repository operations area facilities.

The current design for implementation of the Proposed Action has multiple buildings that would enable a phased construction approach compatible with constrained funding. The primary surface waste handling facilities would include an *Initial Handling Facility*, three separate *Canister Receipt and Closure Facilities*, a *Wet Handling Facility*, and a *Receipt Facility*. In addition, there would be two *aging pads* for use in thermal management. These facilities would enable preparation for disposal of the various types of radioactive wastes after receipt at the geologic repository operations area. Section 2.1.2.1 discusses the waste handling surface facilities and operations more fully.

Once the spent nuclear fuel and high-level radioactive waste received at the repository were packaged in waste packages, the waste packages would be transferred to the subsurface portion of the geologic repository operations area for emplacement in dedicated tunnels (drifts). The waste packages would be aligned end-to-end in these drifts. Emplacement drifts would be excavated in a series of four panels (see Section 2.1.2.2.1), phased to match the anticipated throughput rate of the surface waste handling facilities. In addition, the repository would have other underground excavations. These would include, for example, main drifts to provide access to surface and emplacement drifts, and exhaust mains to release ventilation air from the emplacement drifts. Gradually sloping ramps from the surface to the subsurface facilities would allow workers, equipment, and waste transporters access to and from repository operations. Section 2.1.2.2 discusses the subsurface facilities and operations.

Emplacement of the waste packages in the emplacement drifts would be managed according to the thermal energy or thermal output of the waste packages. In addition to being radioactive, spent nuclear fuel and high-level radioactive waste give off heat, which is referred to as thermal energy or thermal output. When these materials are placed in a confined space, such as an emplacement drift where heat cannot readily dissipate, the surrounding area would become hot. Under the Proposed Action, the thermal output of the waste packages would heat the rock surrounding the emplacement drifts to a temperature higher than the boiling point of water at the repository elevation, 96° Celsius (C) [205° Fahrenheit (F)]. This would cause the small amounts of water in the rock to turn into steam, which would move away from the drifts to a point where temperatures were below the boiling point of water and the steam could condense back to water. Because DOE wants to provide a path for the mobilized water to move downward past the emplacement drifts, the repository has been designed so that there would be a middle region between the drifts (the midpillar region) that remains below the boiling point of water. To accomplish this, DOE would manage the thermal output of the waste packages by selecting for emplacement only those packages that would keep the temperature in the midpillar region below the boiling point of water, as shown in Figure 2-2.

The evaluations of whether a waste package is too thermally hot for emplacement are based on a concept called *thermal energy density*, which is a measure of how heat is distributed over an area. By knowing the thermal characteristics of waste packages it had emplaced in an area of the repository, and the thermal

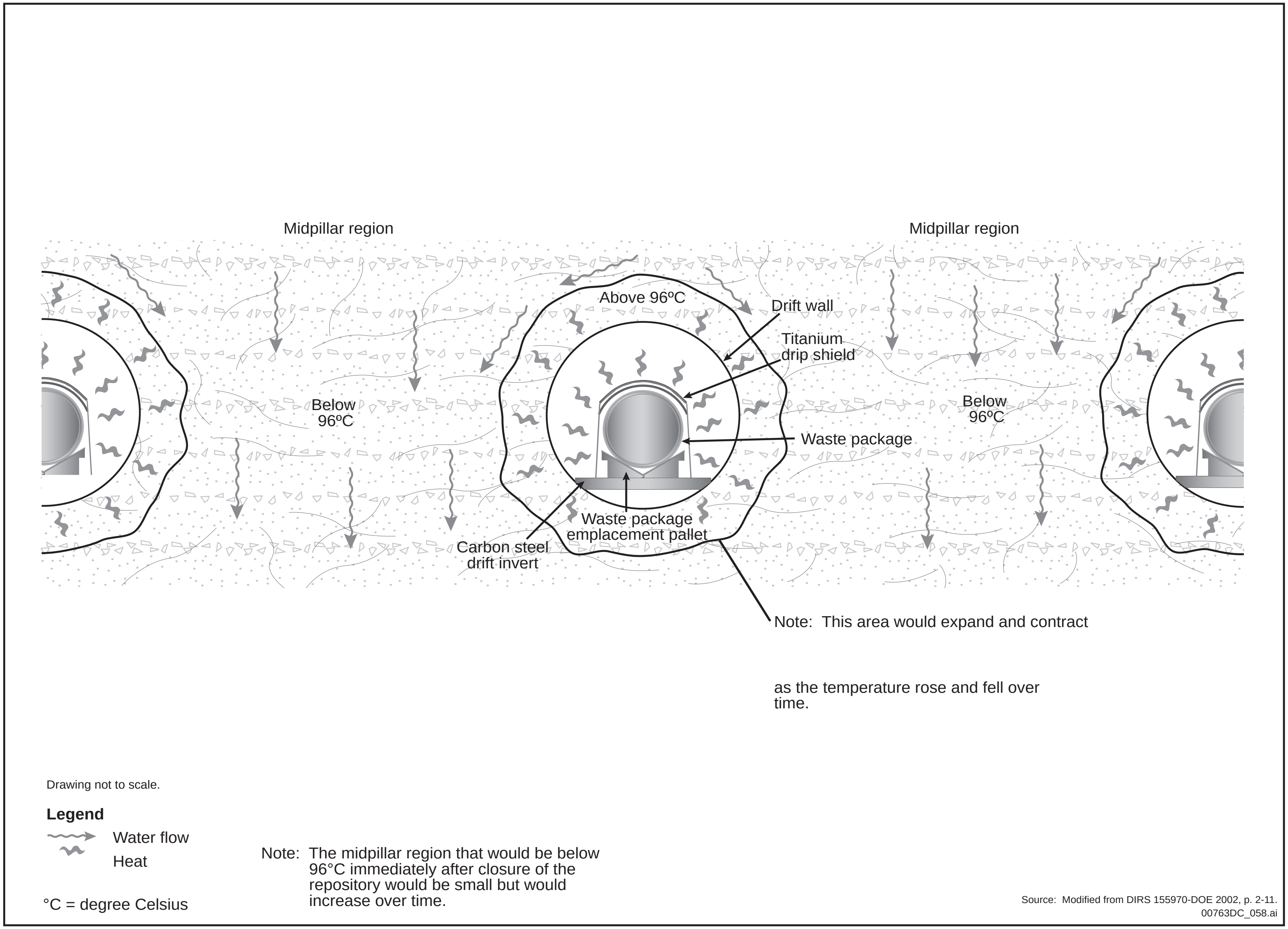


Figure 2-2. Management of waste package emplacement using thermal energy density (artist's concept).

characteristics of waste packages it had available for emplacement, DOE would select, from the available waste packages, those that would be appropriate for the next emplacement in the repository. DOE would make the selections based on calculations that evaluate the effect of the added thermal energy of the additional waste packages on maintaining the midpillar region below the boiling point of water. Management of an upper limit to the thermal energy density for emplacement thus would rely on selecting or blending of waste packages with specific thermal characteristics. DOE would have flexibility in selecting specific waste packages for emplacement. If a certain waste package was too thermally hot for emplacement at the time it was received, DOE would use the aging pads to allow the thermal heat to reduce naturally through radioactive decay, which is responsible for the thermal energy.

DOE's repository design includes five other primary surface facilities to support waste handling and disposal. These are the Central Control Center Facility, the Warehouse and Non-Nuclear Receipt Facility, the Heavy Equipment Maintenance Facility, the Low-Level Waste Facility, and the Emergency Diesel Generator Facility. These facilities would be in the geologic repository operations area; Section 2.1.2.3 describes them more fully. Section 2.1.2.4 describes utilities that would support the geologic repository operations area.

DOE would construct the surface and underground facilities and associated infrastructure, such as the onsite road and water distribution networks and emergency response facilities, in phases to accommodate the expected receipt rates of spent nuclear fuel and high-level radioactive waste. The Department would use two areas, the *South Portal development area* and the *North Construction Portal*, to support *underground facility* construction. Section 2.1.3 describes the South Portal development area and the North Construction Portal. Additional facilities outside the geologic repository operations area would support the project; Section 2.1.4 describes these facilities.

Under the Proposed Action, DOE would conduct a Performance Confirmation Program. *Performance confirmation* refers to the program of tests, experiments, and analyses that DOE would conduct to demonstrate compliance with the repository performance objectives. The Performance Confirmation Program, which would continue until *permanent closure* of the repository, would monitor repository conditions and perform tests to confirm agreement with geotechnical and design assumptions. Under the Proposed Action, emplaced waste packages could be retrieved for at least 50 years after the start of emplacement. Section 2.1.5 describes the Performance Confirmation Program.

When authorized by the NRC, closure of the repository would begin. DOE would install titanium *drip shields* over the waste packages. The drip shields would divert moisture that could drip from the drift walls, as well as condensed water vapor around the waste packages, to the drift floor, thereby increasing the life expectancy of the waste packages. In addition, drip shields would protect the waste packages from rockfalls. After installation of the drip shields, surface facilities would be decontaminated and dismantled. Closure would involve decontamination of the surface handling facilities, backfilling, sealing of underground-to-surface openings, decommissioning and demolition of surface facilities, and restoration of the surface to its approximate condition before repository construction.

After the subsurface facility was closed and sealed, the rock around the emplacement drifts would dry, which would minimize the amount of water that could contact the waste packages for hundreds of years. However, a portion of the rock between the drifts would remain at temperatures below boiling, which would promote drainage of water through the central portions of the rock rather than into the emplacement drifts. DOE would erect a network of monuments and markers around the site surface to warn future generations of the presence and nature of the buried radioactive waste. Section 2.1.6 discusses repository closure further.

The Proposed Action includes construction and operation of a railroad, in an *alignment* in the State of Nevada, to connect the *Yucca Mountain site* to an existing *rail line* in Nevada. The Proposed Action also includes the construction and operation of several facilities that would be necessary for the operation of the railroad. DOE would construct these rail facilities at the same time it constructed the rail line and would coordinate facilities construction with rail line construction. The Rail Alignment EIS analyzes the construction and operation of the railroad and associated facilities; DOE has incorporated that analysis into this Repository SEIS by summary and reference, as discussed further in Section 2.1.7.

Best management practices are an integral part of the Proposed Action. DOE has defined best management practices for this Repository SEIS as the processes, techniques, procedures, or considerations it would employ to avoid or reduce the potential environmental impacts of its Proposed Action in a cost-effective manner while meeting the Yucca Mountain Repository project objectives. While best management practices are not regulatory requirements, they can overlap and support such requirements. Use of best management practices would not replace any local, state, or federal requirements. Best management practices are integral to the design, construction, and operation of the Yucca Mountain Repository and the current design for the repository incorporates them. Chapter 4 discusses resource-specific best management practices for the resource areas to which they apply.

In summary, in this Repository SEIS DOE considers potential environmental impacts associated with the current design for the repository, surface facilities, and transportation. The following subsections describe fuel packaging, geologic repository operations area facilities, construction support, and other project facilities that would be required to implement the Proposed Action, as summarized above. In addition, they describe the Performance Confirmation Program, repository closure, and transportation activities associated with the Proposed Action.

2.1.1 FUEL PACKAGING

In the Yucca Mountain FEIS, DOE evaluated the receipt of commercial spent nuclear fuel under two packaging scenarios. These include the mostly canistered scenario, in which most commercial spent nuclear fuel would be received in dual-purpose canisters, and the mostly uncanistered scenario, in which most commercial spent nuclear fuel would be received uncanistered. In the mostly canistered scenario, the dual-purpose canisters would be opened at the repository and the spent nuclear fuel would be repackaged into waste packages. In the mostly uncanistered scenario, spent nuclear fuel would be transferred from transportation casks to waste packages. In both scenarios, DOE would handle the fuel at the repository in an uncanistered condition prior to loading it into waste packages for emplacement. In the FEIS, all of the DOE materials (spent nuclear fuel and high-level radioactive waste) would be packaged in disposable canisters at the generator sites. These disposable canisters would not have to be opened at the repository and would be placed directly into waste packages for emplacement.

In this Repository SEIS, DOE would operate the repository following a *primarily canistered fuel approach* in which the majority (a goal of 90 percent) of commercial spent nuclear fuel would be packaged at the generator sites in TAD canisters. DOE would use TAD canisters to transport, age, and dispose of commercial spent nuclear fuel at the repository, thereby eliminating the need to ever open the canister and handle that spent nuclear fuel at the repository. The remaining commercial spent nuclear fuel (goal of 10 percent) would arrive at the repository as uncanistered spent nuclear fuel or in dual-purpose canisters. DOE spent nuclear fuel, high-level radioactive waste, and naval spent nuclear fuel would be received in disposable canisters. The Department could ship a small amount of DOE spent nuclear fuel of commercial origin to the repository as uncanistered spent nuclear fuel. At the repository, DOE would place uncanistered spent nuclear fuel directly into TAD canisters. *Aging* of the commercial spent nuclear fuel in TAD canisters or in dual-purpose canisters would, as required, manage thermal output. DOE would place both types of canisters (DOE disposable and TAD) into waste packages before emplacement in the repository.

DEFINITIONS OF PACKAGING TERMS

Aging overpack: A cask specifically designed for aging spent nuclear fuel. TAD canisters and dual-purpose canisters would be placed in aging overpacks for aging on the aging pad.

Disposable canister: A metal vessel for DOE spent nuclear fuel assemblies (including naval spent nuclear fuel) or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, DOE would remove the disposable canister from the transportation cask and place it directly in a waste package. There are a number of types of disposable canisters, including standard canisters, multicanister overpacks, and TAD canisters.

Dual-purpose canister: A metal vessel suitable for storing (in a storage facility) and shipping (in a transportation cask) commercial spent nuclear fuel assemblies. At the repository, DOE would remove dual-purpose canisters from the transportation cask and open them. DOE would remove the spent nuclear fuel assemblies from the dual-purpose canister and place them in a TAD canister before placement in a waste package. The opened canister would be recycled or disposed of off the site as low-level radioactive waste.

Uncanistered spent nuclear fuel: Commercial spent nuclear fuel placed directly into transportation casks. At the repository, DOE would remove spent nuclear fuel assemblies from the transportation cask and place them in a TAD canister before placement in a waste package or site aging overpack.

Shielded transfer cask: A metal vessel used to transfer canisters between waste handling facilities.

Transportation, aging, and disposal (TAD) canister: A canister suitable for storage, shipping, and disposal of commercial spent nuclear fuel. Commercial spent nuclear fuel would be placed directly into a TAD canister at the commercial reactor. At the repository, DOE would remove the TAD canister from the transportation cask and place it directly into a waste package or an aging overpack. The TAD canister is one of a number of types of disposable canisters.

Transportation cask: A vessel that meets applicable regulatory requirements for transport of spent nuclear fuel or high-level radioactive waste via public transportation routes.

Waste package: A container that consists of the corrosion-resistant outer container (Alloy 22 outer cylinder and stainless-steel inner cylinder, the waste form and any internal containers (such as the TAD canister), spacing structure or baskets, and shielding integral to the container. Waste packages would be ready for emplacement in the repository when the outer lid welds were complete and accepted.

The TAD canister is a component of systems that the NRC (1) would certify for the transportation of spent nuclear fuel under 10 CFR Part 71 and for surface storage at the respective commercial sites under

10 CFR Part 72; and (2) would license for repository site transfer, aging, and geologic disposal under 10 CFR Part 63. Under this approach, the use of TAD canisters would minimize the handling of spent nuclear fuel assemblies because operators would seal commercial spent nuclear fuel in TAD canisters at generator sites. The TAD canister design would accommodate both pressurized- and boiling-water reactor spent nuclear fuel. During transport, surface storage, and disposal, DOE would place a TAD canister inside another vessel that provided other necessary functions (for example, radiological shielding, heat dissipation, structural strength, and *corrosion* resistance) as needed for each application. These vessels would include transportation casks, *shielded transfer casks*, *aging overpacks*, and waste packages.

DOE has adopted performance specifications to provide performance objectives for TAD canisters. Revision 0 of the DOE performance specification (DIRS 181403-DOE 2007, all) contains detailed specifications for TAD canisters and the bases for these specifications. Figure 2-3 is a schematic diagram of the TAD canister.

DOE's goal under the Proposed Action is for 90 percent of commercial spent nuclear fuel to be packaged in TAD canisters at generator sites. However, DOE has conducted a sensitivity analysis, provided in Appendix A of this Repository SEIS, that considered the potential case that only 75 percent of commercial spent nuclear fuel could be placed in TAD canisters at commercial sites, with the remainder being loaded into TAD canisters at the repository.

2.1.2 FACILITIES IN THE GEOLOGIC REPOSITORY OPERATIONS AREA AND VICINITY

The operations and facilities where spent nuclear fuel and high-level radioactive waste would be handled would be in the geologic repository operations area, which is shown in Figure 2-4. Waste handling operations would be in a *restricted area* in the geologic repository operations area. During phased construction, the restricted area would separate operational waste handling facilities from waste handling facilities that would be under construction.

This Repository SEIS analyzes implementation of the Proposed Action according to four periods—construction, operations, monitoring, and closure, as listed in Table 2-1. DOE has defined these analytical periods for use in this Repository SEIS to best evaluate potential *preclosure* environmental impacts that could be associated with the Proposed Action, as explained in further detail in Chapter 4. Various activities could occur in each analytical period, but the name of the analytical period implies the major activity that would occur. For instance, during the operations analytical period, construction would be occurring, but operations would be the major activity. Appendix A addresses the impacts of a potentially longer monitoring period. Table 2-1 also lists the corresponding *operational phases* as DOE will describe in its application for construction authorization. The four operational phases indicate when DOE expects specific facilities to be operational under the planned phased construction.

Section 2.1.2.1 describes the surface facilities and operations that DOE would use for waste handling. Section 2.1.2.2 describes the subsurface facilities and repository operations, including ventilation. Section 2.1.2.3 describes the balance of plant facilities, and Section 2.1.2.4 describes utilities for the geologic repository operations area and vicinity.

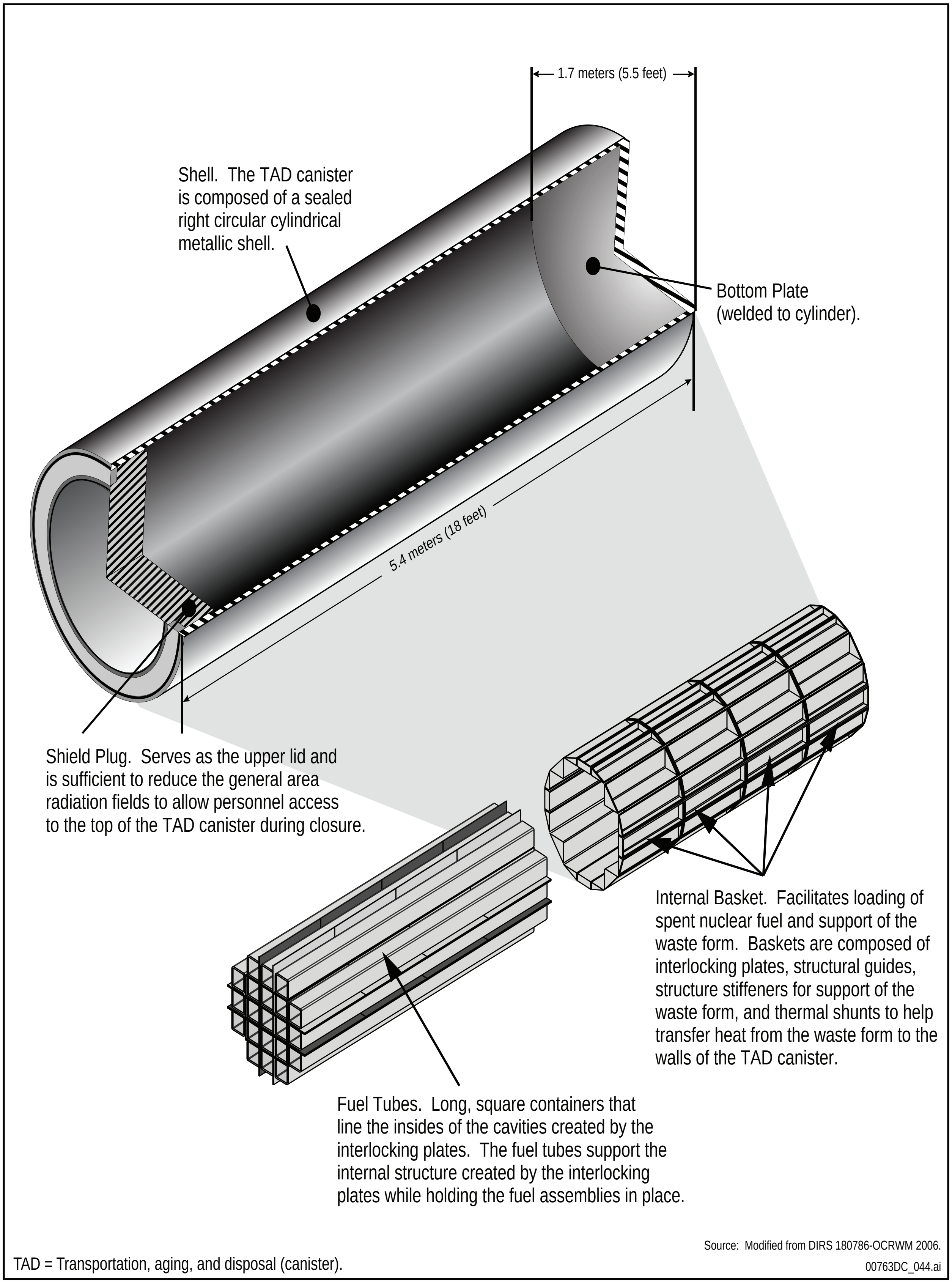


Figure 2-3. TAD canister schematic (artist's concept).

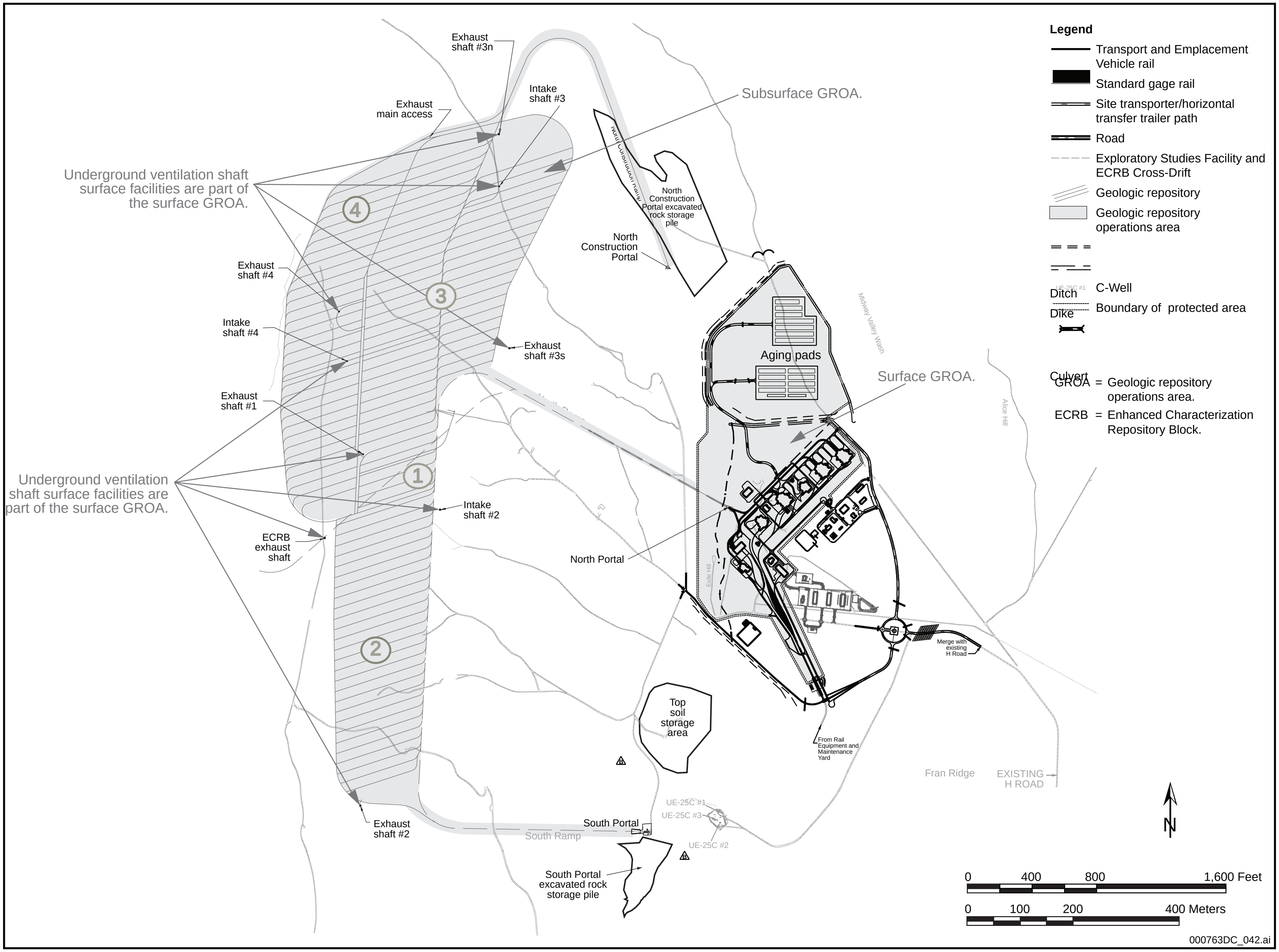


Figure 2-4. Geologic repository operations area.

Table 2-1. Repository SEIS analytical periods and associated construction and activities.

Analytical period duration	Infrastructure construction	Operational phases of surface facilities construction	Subsurface facility development (construction)	Other associated construction or activities
Construction analytical period				
5 years The construction analytical period includes activities that would begin upon receipt of the construction authorization from the NRC and that DOE expects to be completed by the time it received the license to receive and possess radiological materials.	Site preparation activities • Electrical power and distribution system • 138-kilovolt switchyard • 13.8-kilovolt switchgear facility • Two 138-kilovolt transmission lines that would supply power to the main substation • Roads and rail • Domestic water systems • Septic tank and leach field • Sewer and storm-water systems • Storm-water collection system to collect stormwater from roadways, graded areas, and roof surfaces routed to an unlined retention pond • Process nonradioactive wastewater collection system routed to a lined retention pond • Engineering and Safety Demonstration Facility • Hazardous Materials Collection Depot • Use of borrow pits • Explosives Storage Area • Offsite Training Facility • Accommodations to house construction workers • Sample Management Facility • Marshalling yard and warehouse • South Portal development area	Phase 1 • Initial Handling Facility • Wet Handling Facility • Canister Receipt and Closure Facility 1 • Low-Level Waste Facility • Central Control Center Facility • Heavy Equipment Maintenance Facility • Aging pad R • Warehouse and Non-Nuclear Receipt Facility • Two fire water facilities • Cask Receipt Security Station • Central Security Station • Transporter Security Gate • Utility Facility, cooling tower, and evaporation pond • Emergency and Standby Diesel Generator Facilities • Railcar staging area • Truck staging area • Helicopter pad	Subsurface facility development would begin with Panel 1, concurrently with surface construction.	• Developing initial ventilation shafts, which would include shaft pads, batch plants, and electrical utility transmission lines. In addition, there could be a construction laydown and mobilization yard for the management of field activities associated with the ventilation shafts. • Beginning active ventilation of the repository.

Table 2-1. Repository SEIS analytical periods and associated construction and activities (continued).

Analytical period duration	Infrastructure construction	Operational phases of surface facilities construction	Subsurface facility development (construction)	Other associated construction or activities
Operations analytical period				
Up to 50 years The operations analytical period includes activities that would begin upon receipt of a license to receive and possess radiological materials. The operations analytical period would include receipt, handling, aging, emplacement, and monitoring of waste, as well as continued construction of surface and subsurface facilities.	Construction and operations of the North Construction Portal.	Phase 2 • Receipt Facility • Two fire water facilities • Administration Facility and two administration security stations • Fire, Rescue and Medical Facility • Warehouse/Central Receiving • Materials/Yard Storage • Vehicle Maintenance and Motor Pool • Diesel Fuel Oil Storage • Fueling stations • Craft shops • Equipment/Yard Storage Phase 3 • Canister Receipt and Closure Facility 2 • Aging pad P Phase 4 • Canister Receipt and Closure Facility 3 • North Perimeter Security Station	Continued subsurface facility development with Panels 2, 3, and 4 until complete.	• Continuing development of ventilation shafts, which would include shaft pads, batch plants, and electrical utility transmission lines and associated construction laydown and mobilization yard for the management of field activities associated with the ventilation shafts. • Continuing active ventilation of the repository.

Table 2-1. Repository SEIS analytical periods and associated construction and activities (continued).

Analytical period duration	Infrastructure construction	Operational phases of surface facilities construction	Subsurface facility development (construction)	Other associated construction or activities
Monitoring analytical period				
50 years The monitoring analytical period includes activities that would begin with emplacement of the final waste package and continue for 50 years after the end of the operations analytical period.	No infrastructure construction planned.	Possible surface facility construction to support waste retrieval, if necessary.	No subsurface facility development planned.	• Maintaining active ventilation of the repository for at least 50 years after emplacement of the last waste package. • Remotely inspecting waste packages. • Continuing investigations in support of predictions related to postclosure performance • Retrieving waste packages, if necessary.
Closure analytical period				
10 years The closure analytical period includes activities that would begin upon receipt of a license amendment to close the repository and would last 10 years, concurrent with the last 10 years of the monitoring analytical period.	No infrastructure construction planned.	No facility construction planned.	No subsurface facility development planned.	• Decontaminating and dismantling the surface handling facilities[a] • Emplacing the drip shields. • Removing concrete inverts from the main drifts. • Backfilling and sealing subsurface-to-surface openings. • Constructing monuments to mark the site. • Restoring the surface to its approximate condition before repository construction. • Continuing performance confirmation, as necessary.

a. The timeframe for decontaminating and dismantling the surface handling facilities is dependent on the determination that the surface facilities are no longer required to support spent nuclear fuel and high-level radioactive waste handling, processing, emplacement, or retrieval operations. This Repository SEIS assumes that this will occur during the closure analytical period.

DOE = U.S. Department of Energy.

NRC = U.S. Nuclear Regulatory Commission.

DEFINITIONS OF YUCCA MOUNTAIN SITE TERMS

Central operations area: The central operations area is an area in which DOE would develop approximately 0.8 kilometer (0.5 mile) southwest of the geologic repository operations area for all operations, which would include support and replacement of subsurface infrastructure in the Exploratory Studies Facility.

Geologic repository operations area: As defined at 10 CFR 63.2, the geologic repository operations area is "a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted."

North Construction Portal: Portal that would be used for construction of the subsurface facility.

North Portal: An existing portal (current access to the Exploratory Studies Facility) that DOE would use initially for subsurface construction and to emplace waste packages in the subsurface facility.

North Ramp: An existing, gently sloping incline that begins at the North Portal on the surface and extends through the subsurface to the edge of the subsurface facility. It would support waste package emplacement operations.

Portal: A portal is the opening to the subsurface facility that would provide access for construction, equipment, rock removal, and waste emplacement.

Restricted area: The restricted area, as defined at 10 CFR 20.1003 and 10 CFR 63.2, is an area in which DOE would separate waste handling operations from other activities in the geologic repository operations area. During phased construction, the restricted area would separate operational waste handling facilities from waste handling facilities under construction. DOE would monitor the restricted area to ensure adequate safeguards and security for radioactive materials.

South Portal development area: An existing portal and ramp (current access to the Exploratory Studies Facility) that DOE would use for construction of the subsurface facility.

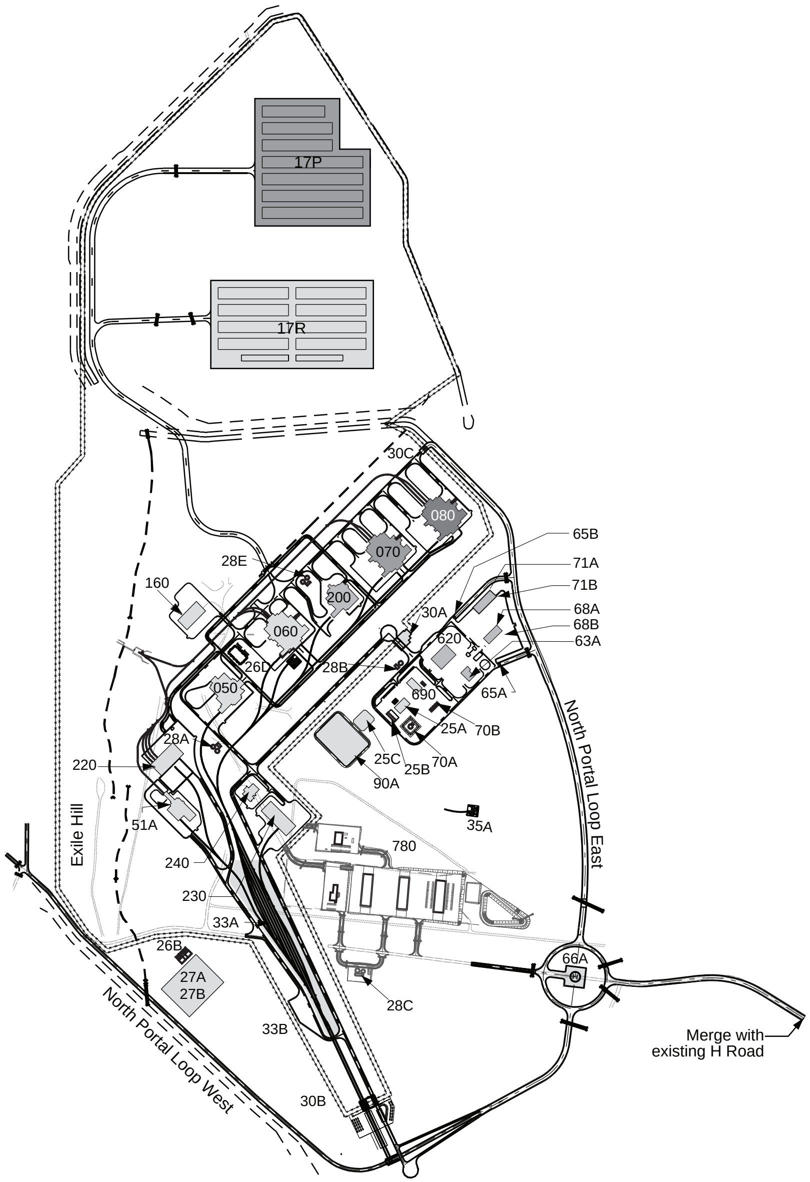
Subsurface facility (subsurface geologic repository operations area): The structure, equipment and systems (such as ventilation), backfill materials if any, and openings that penetrate underground (for example, ramps, shafts, and boreholes, including their seals).

Yucca Mountain Repository (repository): Inclusive term for all areas in the Yucca Mountain site where DOE would construct the proposed facilities to support the proposed repository, including roads.

2.1.2.1 Waste Handling Surface Facilities and Operations

Waste handling surface facilities would be in the restricted area of the geologic repository operations area. Figure 2-5 shows the orientation and layout of the surface facilities in the geologic repository operations area. On Figure 2-5, the surface facilities are grouped according to the four operational phases that would occur under the planned phased construction. The repository would have initial operating capability at the completion of Phase 1 and full operating capability at the completion of Phase 2. The site layout addresses concurrent construction and operations in the geologic repository operations area.

DOE would use six types of surface facilities (eight buildings) or areas for waste handling and would build them in phases: Cask Receipt Security Station, Initial Handling Facility, three Canister Receipt and Closure Facilities, the Wet Handling Facility, the aging pads, and the Receipt Facility. In addition, DOE would use a site transportation network to move transportation casks and waste packages between the waste handling facilities and eventually to the subsurface facility.



LEGEND Initial Operating Capability			
Phase 1			
17R	Aging Pad R	33B	Truck Staging Area
25A	Utility Facility	35A	Septic Tank and Leach Field
25B	Cooling Tower	050	Wet Handling Facility
25C	Evaporation Pond	51A	Initial Handling Facility
26B	Standby Diesel Generator Facility	060	Canister Receipt and Closure Facility 1
26D	Emergency Diesel Generator Facility	66A	Helicopter Pad
27A	Switchyard (138 kilovolts)	90A	Stormwater Retention Pond
27B	13.8 kilovolts Switchgear Facility	160	Low-Level Waste Facility
28A	Fire Water Facility (Central)	220	Heavy Equipment Maintenance Facility
28B	Fire Water Facility (East)	230	Warehouse and Non-Nuclear Receipt Facility
30A	Central Security Station	240	Central Control Center Facility
30B	Cask Receipt Security Station	780	Lower Muck Yard
33A	Railcar Staging Area		
Full Operating Capability			
Phase 2			
28C	Fire Water Facility (South)	70A	Diesel Fuel Oil Storage
28E	Fire Water Facility (North)	70B	Fueling Stations
63A	Fire, Rescue and Medical Facility	71A	Craft Shops
65A	Administration Security Station	71B	Equipment/Yard Storage
65B	Administration Security Station	200	Receipt Facility
68A	Warehouse/Central Receiving	620	Administration Facility
68B	Materials/Yard Storage	690	Vehicle Maintenance and Motor Pool
Phase 3			
17P	Aging Pad P	070	Canister Receipt and Closure Facility 2
Phase 4			
30C	North Perimeter Security Station	080	Canister Receipt and Closure Facility 3

Figure 2-5. Surface layout of the geologic repository operations area and vicinity.

DOE would conduct waste transfer operations in these facilities using mostly remotely operated equipment. The Department would use thick, reinforced concrete shield walls, *shielded* canister transfer, and controlled access techniques to protect workers from *radiation exposure*. The design of the waste handling structures and equipment would withstand the effects of ground motion from *earthquakes* and other events.

DEFINITIONS OF DURATION TERMS

Repository SEIS analytical periods: Four timeframes are defined for use in this Repository SEIS to best evaluate potential preclosure environmental impacts:

- **Construction analytical period: 5 years**—Begins upon receipt of the construction authorization from the NRC and ends prior to receipt of a license to receive and possess radiological materials. Activities would include site preparation, surface construction, and subsurface development.
- **Operations analytical period: 50 years**—Begins upon receipt of a license to receive and possess radiological materials and ends upon emplacement of the final waste package. Activities would include receipt, handling, aging, emplacement, and monitoring of waste, as well as continued construction of surface and subsurface facilities.
- **Monitoring analytical period: 50 years**—Begins upon emplacement of the final waste package. Activities would include maintaining active ventilation of the repository for as long as 50 years, remotely inspecting waste packages, and continuing investigations in support of predictions related to *postclosure* performance.
- **Closure analytical period: 10 years**—Overlaps the last 10 years of the monitoring period and includes activities that would begin upon receipt of a license amendment to close. Activities would include decommissioning and demolishing surface facilities, emplacing drip shields, backfilling, sealing subsurface-to-surface openings, restoring the surface to its approximate condition before repository construction, and constructing monuments to mark the site.

Operational phases: Four stages used in DOE's application for construction authorization to indicate when specific facilities are expected to be operational under the planned phased construction. Operational phases are Phase 1, Phase 2, Phase 3, and Phase 4.

Preclosure: The timeframe from construction authorization to repository closure.

The Initial Handling Facility, Canister Receipt and Closure Facilities, Wet Handling Facility, and Receipt Facility would have a digital control and management information system that would interface with, but have adequate isolation from, the safety components provided with mechanical handling equipment in each facility. In addition, the digital control and management information system would interface with the Central Control Center Facility to enable supervisory control and monitoring of facility operations by Central Control Center Facility operators.

Spent nuclear fuel and high-level radioactive waste would arrive at the repository in a variety of types and sizes, as follows. Figure 2-1 shows how DOE would receive and handle the various waste forms, as described below.

The repository would receive the vast majority of commercial spent nuclear fuel in TAD canisters that were loaded, internally dried and filled by an inert gas to displace oxygen, and closed by the commercial nuclear utilities. Transportation casks arriving at the repository that contained commercial spent nuclear fuel in TAD canisters that required aging would be unloaded in the Receipt Facility. The TAD canisters would be transferred to aging overpacks and moved to the aging pads for thermal management. Once the thermal heat output decayed to an acceptable level, DOE would move the aging overpacks to a Canister Receipt and Closure Facility for packaging of the TAD canisters into waste packages for subsequent subsurface emplacement. TAD canisters that did not require aging would be sent directly to a Canister Receipt and Closure Facility for packaging into a waste package for subsequent subsurface emplacement.

PRIMARY FUNCTIONS OF WASTE PREPARATION AND HANDLING FACILITIES

Aging pads
Provide the capability to age commercial spent nuclear fuel as necessary to meet waste package thermal limits.

Canister Receipt and Closure Facilities
Receive DOE disposable canisters and TAD canisters, load canisters into waste packages, and close the waste packages.

Cask Receipt Security Station
Perform initial waste receipt and inspection.

Initial Handling Facility
Receive high-level radioactive waste and naval spent nuclear fuel canisters, load canisters into waste packages, and close the waste packages.

Receipt Facility
Transfer TAD and dual-purpose canisters, as appropriate, to the Wet Handling Facility, a Canister Receipt and Closure Facility, and the aging pads.

Wet Handling Facility
Handle uncanistered commercial spent nuclear fuel and open and unload dual-purpose canisters; essential purpose is loading TAD canisters.

A small fraction of commercial spent nuclear fuel could arrive in transportation casks as uncanistered pressurized- and boiling-water reactor fuel assemblies. DOE would move transportation casks that arrived at the repository containing uncanistered spent nuclear fuel assemblies to the Wet Handling Facility for transfer to TAD canisters. DOE would dry, inert, and close these TAD canisters. If aging was necessary, the TAD canisters would be transferred to aging overpacks and moved to the aging pads. Once the thermal heat output decayed to an acceptable level, DOE would move the aging overpacks to a Canister Receipt and Closure Facility for packaging of the TAD canisters into waste packages for subsequent subsurface emplacement. If aging was not necessary, the TAD canisters would be transferred via shielded transfer *casks* directly to a Canister Receipt and Closure Facility for packaging into waste packages for subsequent subsurface emplacement.

Commercial spent nuclear fuel could also arrive in sealed dual-purpose canisters. DOE would unload transportation casks that contained commercial spent nuclear fuel in vertical dual-purpose canisters that would require aging in the Receipt Facility. For aging, the dual-purpose canisters would be transferred to aging overpacks and moved to the aging pads for thermal management. Transportation casks that contained horizontal dual-purpose canisters would be moved to a transfer trailer and from there to the aging pad where the horizontal dual-purpose canisters would be pushed into the aging overpack. Once the thermal heat output decayed to an acceptable level, DOE would move the aging overpacks that contained vertical dual-purpose canisters to the Wet Handling Facility for transfer of the spent nuclear fuel into TAD canisters. The horizontal dual-purpose canisters would be removed from the aging overpacks and transferred to the Wet Handling Facility in a shielded transfer cask. Dual-purpose canisters that arrived at the repository that did not require aging would be sent directly to the Wet Handling Facility where the spent nuclear fuel would be transferred into TAD canisters. The TAD canisters would then be moved in shielded transfer casks to the Canister Receipt and Closure Facility for packaging into waste packages for subsequent subsurface emplacement.

High-level radioactive waste, naval spent nuclear fuel, and most DOE spent nuclear fuel would arrive at the repository in disposable canisters. These canisters would be loaded, inerted (except the canisters that contained high-level radioactive waste), sealed, and transported from various waste generation and storage sites. Transportation casks that contained high-level radioactive waste and naval spent nuclear fuel in disposable canisters would be unloaded in the Initial Handling Facility. These canisters would be packaged separately into waste packages in the Initial Handling Facility for subsequent subsurface emplacement. The Initial Handling Facility would not support codisposal of radioactive high-level waste canisters and DOE spent nuclear fuel canisters.

Transportation casks that contained high-level radioactive waste and DOE spent nuclear fuel in disposable canisters would be sent directly to a Canister Receipt and Closure Facility for unloading and transferring into a waste package for subsequent subsurface emplacement. In the Canister Receipt and Closure Facility, the high-level radioactive waste and DOE spent nuclear fuel canisters would be co-disposed in the waste packages. Depending on the waste package configuration, the codisposal would be as follows: five high-level radioactive waste canisters with one spent nuclear fuel canister, four high-level radioactive waste canisters with one spent nuclear fuel canister, or two high-level radioactive waste canisters with two spent nuclear fuel canisters.

Ultimately, the various waste forms would leave the waste handling facilities packaged uniformly in waste packages for repository emplacement.

2.1.2.1.1 *Cask Receipt Security Station*

The Cask Receipt Security Station would be at the south end of the surface geologic repository operations area (Figure 2-5, Facility 30B). The Cask Receipt Security Station would be the point of receipt of all nuclear and direct nuclear support-related shipments. Shipments of spent nuclear fuel and high-level radioactive waste would arrive at the Cask Receipt Security Station on commercial railcars that carried rail transportation casks and on truck trailers that carried truck transportation casks. Upon arrival, the shipments would be inspected and custody of, or responsibility for, the transportation casks would be transferred from the transportation system to the repository. Casks, still on commercial railcars or truck trailers, would be moved from the Cask Receipt Security Station to a staging area in the restricted area of the repository to await processing into one of the waste handling facilities. Incoming empty waste packages, TAD canisters, and shielded transfer casks would also arrive at the Cask Receipt Security Station on railcars and truck trailers before their transfer to the staging area and on to the Warehouse and Non-Nuclear Receipt Facility. Empty *transportation casks* would be held in the staging area awaiting shipment off the site for reuse.

2.1.2.1.2 *Initial Handling Facility*

The Initial Handling Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 51A). The Initial Handling Facility would receive rail and truck transportation casks that contained high-level radioactive waste or naval spent nuclear fuel canisters. The naval spent nuclear fuel would be delivered in rail transportation casks. The high-level radioactive waste would be delivered in either rail or truck transportation casks. No other waste forms would be handled in the Initial Handling Facility. The Initial Handling Facility would have the capability to prepare the truck and rail transportation casks for unloading, transfer the disposable canisters into waste packages, close and seal the waste packages, and transfer the completed waste packages to a transport and emplacement vehicle for movement to the subsurface.

2.1.2.1.3 *Canister Receipt and Closure Facilities*

When the repository was fully operational, there would be three Canister Receipt and Closure Facilities of identical design for the packaging of canisters into waste packages. The three facilities would be in a row in the central part of the surface geologic repository operations area (Figure 2-5, Facilities 060, 070, and 080).

The Canister Receipt and Closure Facilities would have the ability to receive and handle DOE disposable canisters and TAD canisters, to transfer them into waste packages, to close the waste packages, and to load the waste packages on transport and emplacement vehicles for subsequent emplacement in the subsurface facility. The facilities also would have the ability to transfer vertical dual-purpose canisters from transportation casks into aging overpacks and then onto site transporters for transport to an aging pad and to transfer horizontal dual-purpose canisters to the transfer trailer for transport to an aging pad, where they would be pushed into the aging overpack.

The facilities would have a limited ability for repair of damaged casks and canisters. Any repair work for canisters or waste packages that required underwater work would be performed in the Wet Handling Facility, which would have the ability to place a damaged container in the spent fuel pool and open it underwater.

Uncanistered spent nuclear fuel assemblies would not be processed in the Canister Receipt and Closure Facilities, and casks would not be opened inside the facility.

2.1.2.1.4 *Wet Handling Facility*

The Wet Handling Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 050). This facility would provide support for cask preparation, receipt and opening of sealed dual-purpose canisters and transfer of spent nuclear fuel into TAD canisters underwater, closure of TAD canisters, loading of aging overpacks onto site transporters for transport to an aging pad, and loading of TAD canisters onto site transporters for transfer to a Canister Receipt and Closure Facility where a TAD canister could be transferred into a waste package for subsequent emplacement. The Wet Handling Facility would have a 15.2-meter (50-foot)-deep spent fuel pool. The pool would have a limited-capacity in-process spent nuclear fuel staging area. This would consist of storage racks with the capacity to hold approximately 80 pressurized-water reactor spent nuclear fuel assemblies and 120 boiling-water reactor spent nuclear fuel assemblies.

The Wet Handling Facility would receive dual-purpose canisters in various ways, including (1) in aging overpacks from the aging pads, (2) in rail transportation casks, and (3) in shielded transfer casks from the

Receipt Facility and aging pads. The facility also would receive uncanistered spent nuclear fuel assemblies in transportation casks transported from the rail or truck *buffer areas*.

The uncanistered spent nuclear fuel assemblies from the transportation casks and the spent nuclear fuel in the dual-purpose canisters would be repackaged into TAD canisters at the Wet Handling Facility. The transportation casks that contained uncanistered spent nuclear fuel assemblies would be moved to the facility's pool for lid removal and transfer of the uncanistered fuel assemblies to an empty TAD canister or to the pool staging rack. At this point, the spent nuclear fuel assemblies would be blended to ensure that the loaded TAD canister thermal limits would not be exceeded. Dual-purpose canisters would be opened outside the pool and then moved into the pool for transfer of the commercial spent nuclear fuel to TAD canisters or the pool staging rack.

Once the TAD canisters were loaded, dried, *inerted*, and sealed, they would be transported to either the aging pads for thermal management or a Canister Receipt and Closure Facility for packaging into waste packages.

The facility also would contain an area to facilitate the handling and limited repair of casks and TAD canisters. In addition, the facility would prepare the unloaded dual-purpose canisters for removal from the facility.

2.1.2.1.5 *Aging Pads*

The surface layout includes two aging pads to provide space for aging commercial spent nuclear fuel. The aging pads would be at the north end of the surface geologic repository operations area (Figure 2-5, Facilities 17P and 17R). The pads would enable aging of commercial spent nuclear fuel as necessary to meet waste package thermal limits. The principal components of the aging system would be overpacks that contained either TAD canisters or dual-purpose canisters positioned on an aging pad. The aging pads would accommodate up to 21,000 MTHM of commercial spent nuclear fuel.

The aging pads would receive aging overpacks from the Receipt Facility, Wet Handling Facility, and Canister Receipt and Closure Facilities and would send aging overpacks to the Wet Handling Facility and Canister Receipt and Closure Facilities. The aging pads would also receive transportation casks that contained horizontal dual-purpose canisters and later send them in shielded transfer casks to the Wet Handling Facility.

2.1.2.1.6 *Receipt Facility*

The Receipt Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 200). This facility would transfer TAD and dual-purpose canisters that arrived on commercial railcars carrying rail transportation casks to the Wet Handling Facility, a Canister Receipt and Closure Facility, and the aging pads. TAD and dual-purpose canisters would be transferred to these facilities in a shielded transfer cask or aging overpack, and horizontal dual-purpose canisters would be transferred to the aging pads in transportation casks. In addition, the Receipt Facility would prepare unloaded transportation casks for return to the national transportation system. Until the Receipt Facility was operational, the Initial Handling Facility or a Canister Receipt and Closure Facility would provide the receipt and transfer functions of the Receipt Facility.

2.1.2.1.7 *Site Transportation Network*

The site transportation network would consist of rail lines and roads that connected the waste handling facilities, staging areas, aging pads, and emplacement *portal*. Onsite canister transfer would be accomplished in shielded transfer casks, transportation casks, or aging overpacks by shielded site transporters. The shielded site transporters would be hydraulically self-propelled and powered by a diesel engine or electric motor when operated outdoors and by an electric motor when used inside buildings. Each site transporter would include a cask restraint system to prevent uncontrolled cask movement during transport. The site transporters would be all-weather vehicles designed to operate in rain and snow over the temperature and humidity range of the site.

2.1.2.1.8 *Waste Package Transport to the Subsurface Facility*

After loading, the waste packages would be welded closed and placed horizontally on an emplacement pallet in the Initial Handling Facility or a Canister Receipt and Closure Facility. The emplacement pallet would support the waste package in a horizontal position in the emplacement drift. Pallets would be fabricated from *Alloy 22* (UNS N06022) and Stainless Steel Type 316, which are corrosion-resistant, and which DOE chose based on the potential corrosion mechanisms in the repository environment.

A transport and emplacement vehicle would transport the waste packages from the Initial Handling Facility or Canister Receipt and Closure Facility to a subsurface emplacement drift through the *North Portal* and down the North Ramp to the appropriate emplacement drift. The waste package and the emplacement pallet would be transported as a single unit.

The transport and emplacement vehicle would be a specialized, shielded rail vehicle designed to move waste packages safely from the surface facilities into the subsurface facility for emplacement. The vehicle design would prevent uncontrolled movement that could lead to a breach of a waste package and withstand rockfall occurrences without jeopardizing the structural integrity of the waste package. To accommodate the high radiation environment of the emplacement drifts, the transport and emplacement vehicle would be controlled by an onboard network of programmable logic controllers and operators in the Central Control Center. Figure 2-6 shows the transport and emplacement vehicle.

2.1.2.2 Subsurface Facilities and Operations, Including Ventilation

DOE would excavate horizontal tunnels, or drifts, in Yucca Mountain for waste emplacement. The subsurface facilities would consist of a main drift, which would be a 7.6-meter (25-foot)-diameter tunnel that would provide access to smaller emplacement drifts. Emplacement drifts would be 5.5-meter (18-foot)-diameter tunnels. The design is based on an emplacement drift spacing of 81 meters (270 feet). Under the current repository design, the total repository emplacement area to accommodate 70,000 MTHM is about 6 square kilometers (1,500 acres).

Approximately 68 kilometers (42 miles) of emplacement drifts would be excavated in four panels. About 11,000 waste packages and their emplacement pallets would be placed in these drifts. DOE would use mechanical excavation methods such as electric-powered tunnel boring machines to excavate drifts (Figure 2-7), as well as road headers, drill and blast using explosives, and raise borers, depending on the application of the tunnel or shaft.

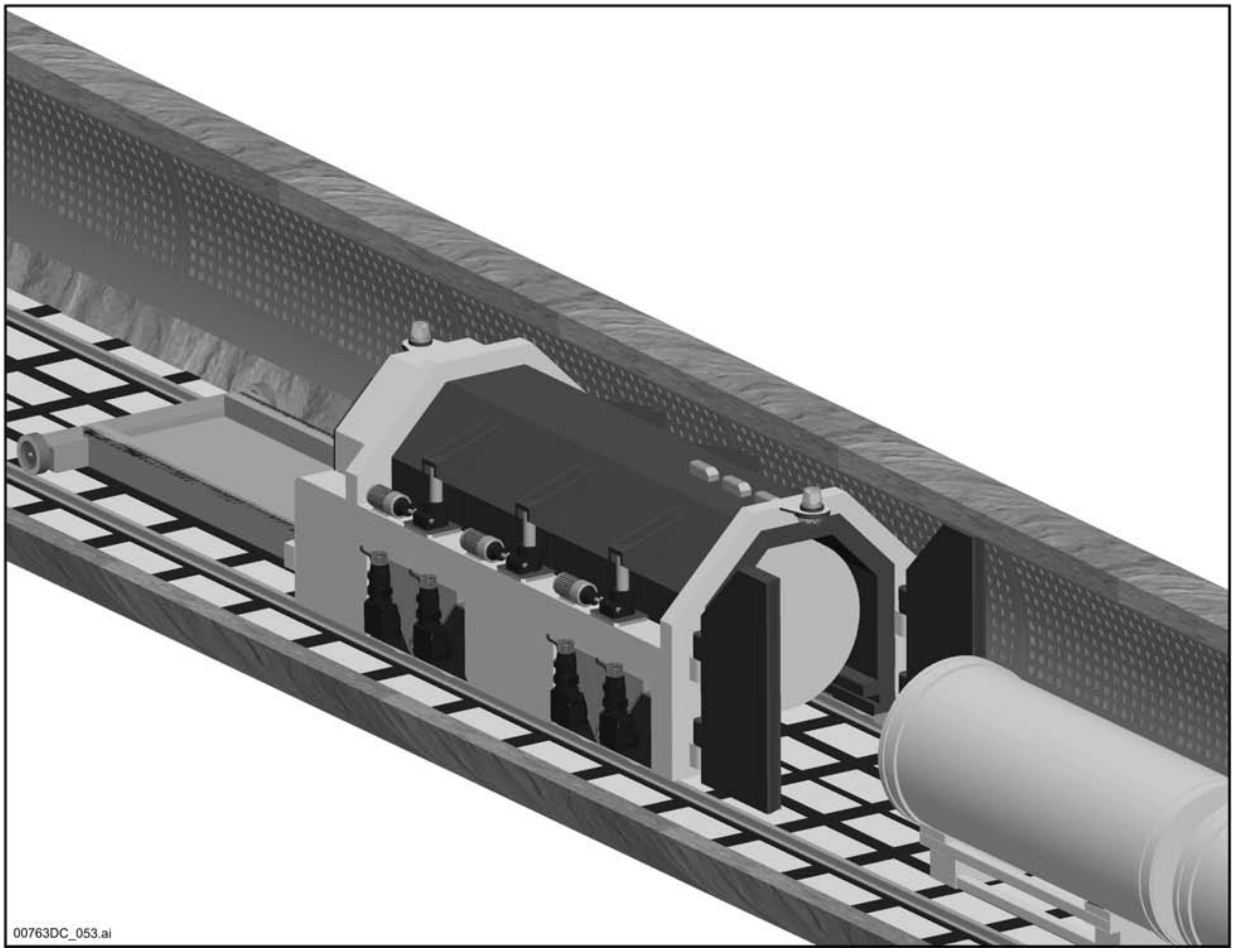


Figure 2-6. Transport and emplacement vehicle placing waste package in emplacement drift (artist's concept).

Ground support would protect workers by providing tunnel stability and preventing rockfall. Ground support would differ for the various types of underground openings. Ground support for emplacement drifts would consist of initial ground support and final ground support.

The initial ground support would provide worker safety until installation of the final ground support system. The initial ground support would consist of carbon-steel frictional rock bolts and wire mesh based on industry standard materials. The initial ground support would be installed in the drift crown only, immediately after excavation. The wire mesh would be removed before installation of the final ground support, while the initial rock bolts would remain in place. The purpose of this initial ground support would be to protect personnel from loosened rock during the tunneling process, and to protect the geologic mapping personnel who could follow the tunnel boring machine in selected locations.

Final ground support for the emplacement drifts would be installed before the drifts were equipped with utilities and invert structures. Final ground support would consist of friction rock bolts, 3 meters (9.8 feet) long, spaced at 1.3-meter (4-foot)-intervals, and perforated metal sheets, 3 millimeters (0.12 inch) thick, installed in a 240-degree arc around the drift periphery along the entire drift length. Both the friction bolts and perforated metal sheets would be made of Stainless Steel Type 316 or equivalent. This

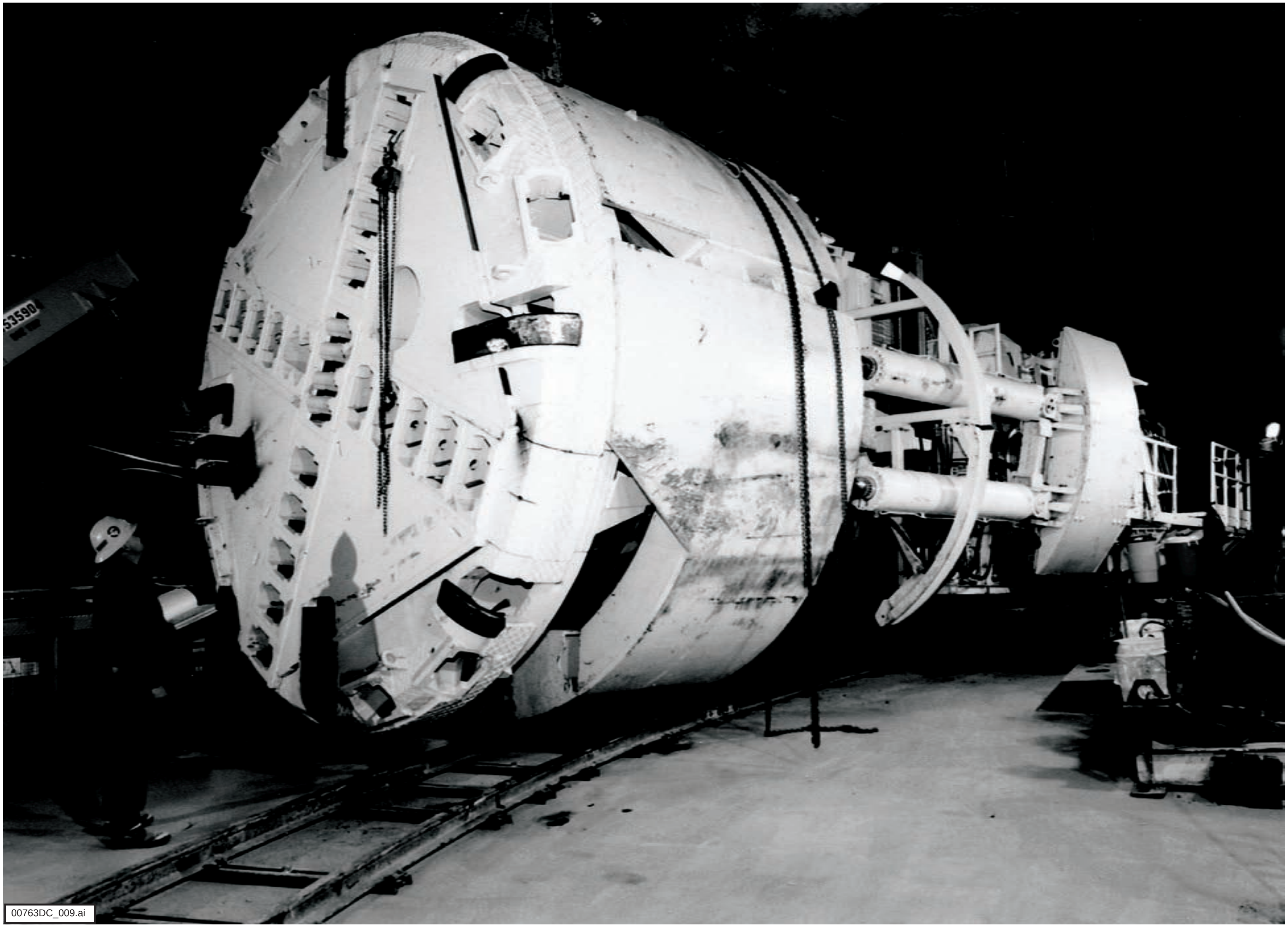


Figure 2-7. Tunnel boring machine.

material is corrosion-resistant, and DOE chose it based on the potential corrosion mechanisms in the repository environment during the preclosure analytical periods.

The ground support for the portals would consist of fully grouted rock bolts with fiber-reinforced shotcrete installed around the portal frontal and lateral faces. Due to the functions that the ramps provide as access ways for personnel and, in the case of the North Ramp, for waste package transportation, fully grouted rock bolts would be supplemented with a lining of shotcrete to enhance the ground support function in the three ramps.

Ground support design at intersections between the access main drifts and turnouts or between exhaust main drifts and emplacement drifts would consist of fully grouted rock bolts with fiber-reinforced shotcrete and lattice girders as necessary. Fully grouted rock bolts with welded wire mesh would be used for ground support in most of the nonemplacement openings, which would include access mains, exhaust mains, turnouts, and tunnel boring machine launch chambers.

Ventilation would be required for *maintenance* of airflow to the subsurface facilities during construction (development), emplacement, and monitoring. In addition, it would provide positive-pressure ventilation flow for the development of the repository and negative-pressure ventilation flow to the emplacement drifts. Based on the current repository design, subsurface facility ventilation would consist of two operationally independent and separate systems: the development ventilation system and the emplacement ventilation system. Isolation barriers would physically separate the development side from the emplacement areas. These systems would enable concurrent development of emplacement drifts on one side of the isolation barriers and waste emplacement in operational emplacement drifts on the other side. The two systems would have independent airflow networks and fan systems that operated concurrently. The development ventilation system would be a supply system, with the primary purpose of ensuring the health and safety of subsurface personnel. The emplacement ventilation system would be an exhaust system with the primary purpose of attaining thermal goals in the repository.

Based on the current design, the overall ventilation system would consist of three intake *shafts* and six exhaust shafts. The three ramps would act as additional ventilation intakes. Ventilation shafts are vertical openings, typically circular, excavated by mechanical means or by drill-and-blast techniques. The repository ventilation shafts would be either 4.9 meters (16 feet) or 7.6 meters (25 feet) in diameter. These nine shafts and three ramps would serve more than 100 emplacement drifts in the four repository waste *emplacement panels*.

The shafts would be near the crest of Yucca Mountain in an area that would have roads, shaft pads, and electrical utility transmission lines. The ventilation rate across each emplacement drift would be 15 cubic meters per second (approximately 32,000 cubic feet per minute). Figure 2-4 shows the main and emplacement panels and ventilation shafts.

2.1.2.2.1 *Subsurface Facility Emplacement Panels*

The subsurface facility would be divided into four waste emplacement panels that would be developed and made operational in sequence over a period of years, planned to coincide with the receipt of waste. Emplacement panels can best be described as groups of isolated tunnels set aside for waste disposal. Each panel would consist of multiple emplacement drifts in which DOE would dispose of the waste packages. Each panel would share common subsurface facilities for access, monitoring, and ventilation

(Figure 2-4). The repository panels and their associated *engineered barriers* would function in conjunction with the *natural barriers* to provide waste containment and isolation during the preclosure and postclosure periods.

The emplacement panels would be excavated in rock formations that DOE has selected because of their attributes for waste containment and isolation. The excavations dedicated to waste emplacement would be equipped to (1) support waste emplacement and retrieval equipment, (2) contain a stable invert structure capable of holding the waste packages on their emplacement pallets and drip shields in stable positions, and (3) provide ground support systems capable of maintaining the safety and integrity of the excavations throughout the preclosure period.

As described below for Panel 1, construction would begin at a location in the existing *Exploratory Studies Facility* tunnel. DOE developed the Exploratory Studies Facility as the main test facility for collection of detailed geologic, hydrologic, and geophysical information on the welded volcanic *tuff* of the Topopah Spring unit identified as a potential host horizon for permanent spent nuclear fuel and high-level radioactive waste disposal. The Department began construction of the Exploratory Studies Facility in September 1994, using a 7.6-meter (25-foot)-diameter tunnel boring machine that excavated a 7.9-kilometer (4.9-mile), U-shaped tunnel into Yucca Mountain. The Exploratory Studies Facility has three main sections: (1) the North Ramp, which descends 2.8 kilometers (1.7 miles) into the mountain; (2) the main area of the facility, approximately 213 meters (700 feet) below the surface of the ramp entrance and running approximately 3.2 kilometers (2.0 miles) through the Topopah Spring unit of the mountain; and (3) the South Ramp, which ascends 2.2 kilometers (1.4 miles) back to the surface at the South Portal development area.

Panel 1

Construction would start with Panel 1 because this proposed location would be easily accessible from the North Portal. This panel would require the least amount of development work because of its small size and because it would use existing excavations for access. In addition, Panel 1 would require the least volume of ventilation. Panel 1 would be in the central section of the overall layout. Excavation and construction of six emplacement drifts and one exhaust shaft would proceed from north to south. DOE would use three emplacement drifts for initial emplacement while development of the remaining drifts in the panel continued concurrently with that operation. The use of an observation drift in Panel 1 would support the Performance Confirmation Program at this time. Isolation barriers would be constructed to separate the initial emplacement area from the continuing construction in Panel 1. This panel would have six emplacement drifts.

Panel 2

After Panel 1 excavation was complete, DOE would excavate Panel 2. This panel would be accessed from the South Portal. Aside from Panel 1, Panel 2 would require the least amount of preparation for waste emplacement. Excavation and construction of emplacement drifts would proceed from north to south. This panel would have two exhaust shafts and one intake shaft and would have 27 emplacement drifts.

Panel 3

After Panel 2 excavation was complete, Panels 3E and 3W would be excavated. These panels would share a common access main drift and would be excavated alternately from south to north. Substantially more development would be needed to prepare Panel 3 and associated drifts for emplacement, in comparison to Panels 1 and 2. The North Construction Portal and North Construction Ramp, five ventilation shafts, and the excavation of access and exhaust mains would be constructed to support development activities for Panels 3E and 3W. The emplacement drifts for these two panels would be filled alternating from east to west, starting from the south and working north. Panels 3E and 3W would have a combined total of 45 emplacement drifts.

Panel 4

Panel 4 would be excavated in the western limit of the subsurface geologic repository operations area and accessed through the North Construction Portal. Panel 4 would be excavated concurrently with Panel 3. Construction activities would not be as extensive as those for Panels 3E and 3W. However, for reasons related to ventilation isolation, rock haulage, and construction access, waste emplacement in Panel 4 would occur last. The emplacement drifts in Panel 4 would be filled from the south to the north. This panel would have 30 emplacement drifts.

2.1.2.2.2 *Waste Emplacement in the Subsurface Facility*

Waste packages would be disposed of in dedicated emplacement drifts, supported on emplacement pallets, and aligned end-to-end on the drift floor (Figure 2-8). Emplacement pallets would be fabricated from Alloy 22 plates and stainless steel. The supports would have a V-shaped top surface to accept all waste package diameters. The waste package would not be mechanically attached to the pallet; it would rest on the V-shaped surfaces of the pallet. Because the ends of the waste package would extend past the ends of the emplacement pallet, the waste packages would be placed end-to-end, as close as 10 centimeters (4 inches) from each other, without interference from the pallets.

The emplacement pallet and waste package would be moved as one unit from a Canister Receipt and Closure Facility or the Initial Handling Facility to the emplacement drift. The emplacement pallet would support the waste package in the drift throughout the preclosure period. When the shielded transport and emplacement vehicle arrived at the assigned location in an emplacement drift and the emplacement access doors on the transport and emplacement vehicle opened, the emplacement pallet with its waste package would be lowered from the vehicle to its emplacement location in the drift.

2.1.2.2.3 *Engineered Barriers*

Engineered barriers include those components in the emplacement drifts that would contribute to waste containment and isolation. The design would include the following components as engineered barriers: (1) waste package, (2) emplacement pallet, (3) emplacement drift invert, and (4) drip shield. Figure 2-9 shows a cross-section of a waste package, pallet, emplacement drift invert, and drip shield. The following sections summarize the details of these components.

Waste Package

The waste packages would consist of two concentric cylinders. The inner cylinder would be made of a modified Stainless Steel Type 316, and the outer cylinder would be made of corrosion-resistant, nickel-based Alloy 22. The Alloy 22 cylinder would provide long-term protection for the internal components of the waste package, including the stainless-steel inner cylinder, from corrosion and contact with water.

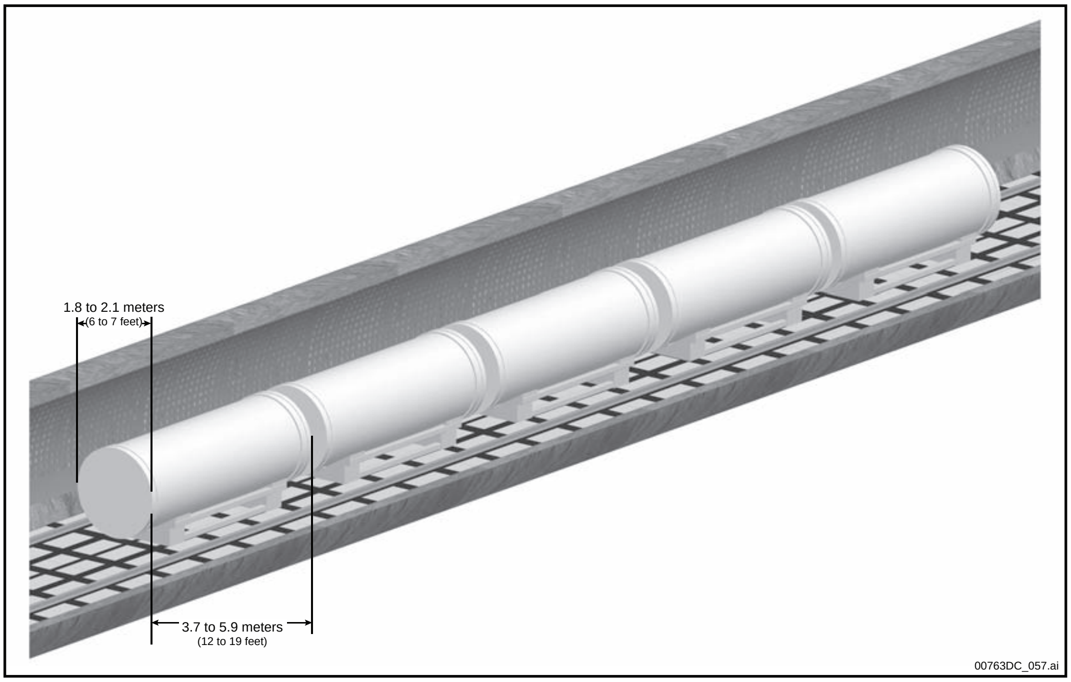


Figure 2-8 Emplacement pallets loaded with waste packages in an emplacement drift (artist's concept).

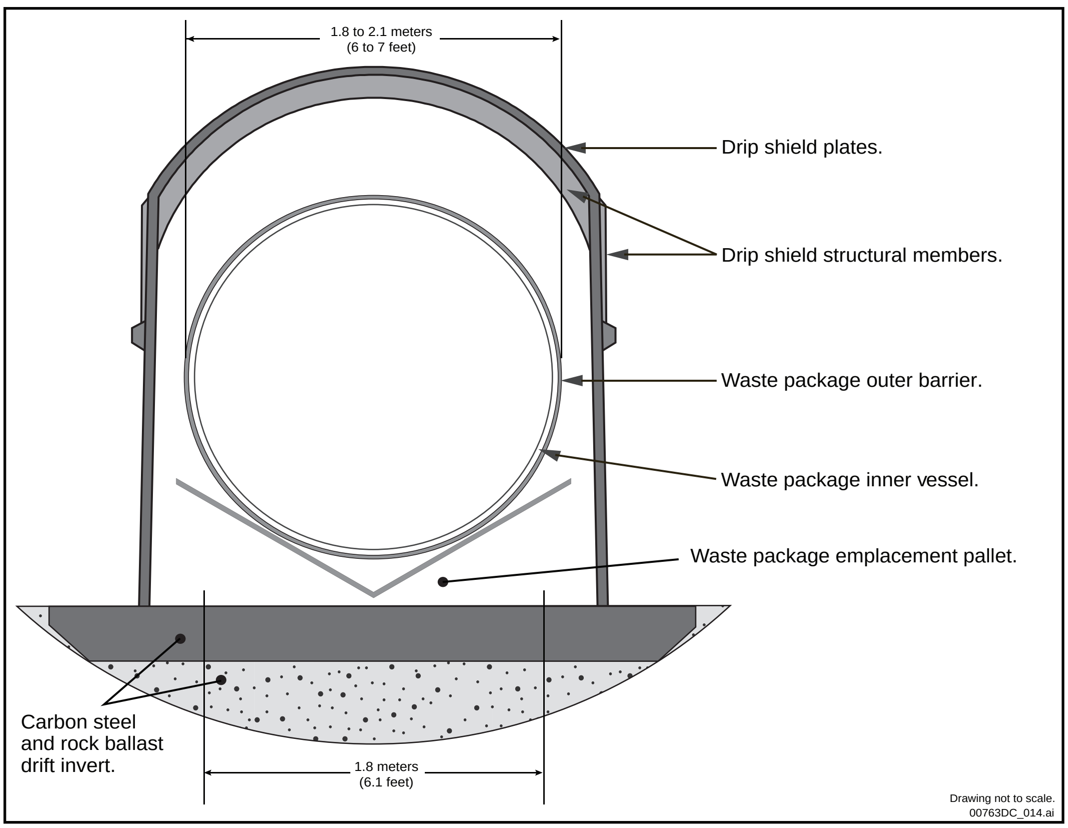


Figure 2-9 Cross section of a waste package, pallet, emplacement drift invert, and drip shield (artist's concept).

The Type 316 stainless-steel cylinder would provide structural support for the thinner Alloy 22 cylinder. The basic waste package design would be the same for the various waste forms. However, the sizes and internal configurations would vary to accommodate the different waste forms.

Under the current design, there would be minor changes to the waste package design from that described in the Yucca Mountain FEIS. Changes include (1) a new outer lid and closure weld techniques; (2) reduced stainless-steel inner lid thickness, including a spread ring closure for all waste packages except the DOE codisposal waste package, which would have a thicker inner lid that also served as a shield plug; (3) removal of the previously used trunnion collars so the waste package would be lifted only by the pallet; and (4) modification of the gap between the inner and outer vessel to better accommodate thermal expansion.

Corrosion tests on Alloy 22 have been and continue to be performed in a variety of thermal and chemical environments. Analyses indicate that Alloy 22 lasts considerably longer than 10,000 years, in the range of expected environments at the proposed repository (DIRS 166894-BSC 2004, all; DIRS 169766-BSC 2004, all; DIRS 170878-BSC 2004, all).

Emplacement Pallet

Emplacement pallets would support the waste packages in the drift as described in Section 2.1.2.2.2. DOE considers the emplacement pallet to be an engineered barrier system component because its Alloy 22 components would reduce the potential for damage to the waste package that resulted from a *seismic* event and would maintain the waste package in position separate from other emplacement drift components during the postclosure period. The long-lasting components of the emplacement pallet would be relatively flexible in comparison to the waste package and would have a cushioning effect on a waste package subjected to the dynamics of a seismic event.

Emplacement Drift Invert

The emplacement drift invert would include structures and materials at the bottom of the emplacement drifts that supported the pallets and waste packages, drift rail system, and drip shields. The emplacement drift invert structure would consist of two components: the steel invert structure and the ballast fill. The steel invert structure would provide a platform to support the emplacement pallets, waste packages, and drip shields. The ballast would fill the voids between the drift rock and the invert steel frame, and the level of the ballast would be brought up to the top level of the steel. DOE has selected steel and crushed tuff (from the repository excavations) as ballast materials for the invert components based on their structural strength properties, compatibility with the emplacement drift environment, and expected longevity.

After repository closure, the crushed tuff in the invert would provide a layer of material below the waste packages that would (1) slow the movement of *radionuclides* into the host rock in the event of a waste package breach, and (2) provide support in the event of pallet failure after tens of thousands of years.

Drip Shield

A drip shield would protect each waste package in the repository. After the NRC approved a decision to close the repository, DOE would install titanium drip shields to protect waste packages from dripping water and rockfall. The drip shield would be fabricated from Titanium Grade 7 plates for the water diversion surfaces, Titanium Grade 29 for the structural members, and Alloy 22 for the bases. The Alloy 22 bases would be mechanically attached to the titanium drip shield side plates because the two materials cannot be welded together. The Alloy 22 bases would prevent direct contact between the titanium and the carbon-steel members in the invert, which could result in hydrogen embrittlement of the titanium. All the drip shields would be of a uniform size and would interlock with each other to form a continuous enclosure over all the waste packages.

Under the current design, there would be minor changes to the drip shield design from that proposed in the Yucca Mountain FEIS. The drip shields would be taller, increasing the distance from the waste package to the drip shield to minimize impacts from rockfall. Longitudinal stiffener beams would be added to provide greater strength for bending loads along the axial length of the drip shields, and the new design has simplified the handling and interlocking features.

2.1.2.3 Balance of Plant Facilities

The balance of plant facilities would be those that would not be directly involved in radioactive waste handling and would not be directly applicable to the importance to safety structures, systems, and components. The primary balance of plant facilities would be in the surface geologic repository operations area (Figure 2-4) and would consist of the Central Control Center Facility, Warehouse and Non-Nuclear Receipt Facility, Heavy Equipment Maintenance Facility, Low-Level Waste Facility, and Emergency Diesel Generator Facility. The following sections discuss these and other supporting balance of plant facilities in the surface geologic repository operations area.

2.1.2.3.1 *Central Control Center Facility*

The Central Control Center Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 240) and would provide centralized communications and site-wide monitoring and control. The facility would provide space and layout for three major areas: the Central Control Center, a central alarm station, and a central communications room. The Central Control Center would be the area from which the entire repository was monitored, selected systems were controlled, and other systems were controlled on a supervisory level. The central alarm station would include safeguards and security measures, support the material control and accounting program, and provide protective measures for personnel and property. The central communications room would provide the capability to communicate with offsite locations, including emergency response and other DOE facilities.

2.1.2.3.2 *Warehouse and Non-Nuclear Receipt Facility*

The Warehouse and Non-Nuclear Receipt Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 230). The facility would be a nonradiological facility that would receive empty waste packages, empty TAD canisters, aging overpacks, and emplacement pallets from offsite manufacturers. It would have the capability for inspection, cleaning, and staging of these components for use by the Canister Receipt and Closure Facilities, the Receipt Facility, the Initial Handling Facility, and the Wet Handling Facility.

2.1.2.3.3 *Heavy Equipment Maintenance Facility*

The Heavy Equipment Maintenance Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 220) and would provide the maintenance capability for the heavy-load handling equipment (such as the site transporter) used to transport and handle spent nuclear fuel and high-level radioactive waste in the geologic repository operations area.

The Heavy Equipment Maintenance Facility would have overhead cranes, tow vehicles, forklift trucks, a machine shop, a welding shop, and large maintenance bays for equipment parking and laydown space. In addition, this facility could receive, stage, handle, and manage waste package emplacement pallets. Emplacement equipment would move to the Heavy Equipment Maintenance Facility for repair and routine maintenance by way of the North Ramp.

DOE would use the Heavy Equipment Maintenance Facility to stage equipment and recover from unscheduled mobile equipment outages. Operations that involved tow vehicles, mobile cranes, heavy-lift equipment, and tractor-trailer operations could be planned and implemented from this facility.

2.1.2.3.4 *Low-Level Waste Facility*

The Low-Level Waste Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 160). The facility design would include the collection, processing, and preparation for offsite shipment for the disposal of *low-level radioactive waste* streams generated during the handling of high-level radioactive waste and spent nuclear fuel. DOE would control and dispose of site-generated low-level radioactive waste in a DOE low-level waste disposal site, a site in an *Agreement State*, or in an NRC-licensed site.

The Low-Level Waste Facility would contain storage for wastes in boxes, drums, filters, and high-integrity containers. Empty dual-purpose canisters would be stored in the facility for eventual disposal at an offsite low-level waste facility or offsite shipment for recycling.

Waste forms that DOE would handle at this facility include materials such as:

- Dry, solid low-level radioactive waste
  - Plastic, metal, paper, cloth, and rubber items
  - Wood
  - Concrete
  - Empty dual-purpose canisters

- Wet, solid low-level radioactive waste
  - Spent ion exchange media, mechanical filters, and material collected (other than high-level radioactive waste) by the pool vacuum system
  - Mop heads, wet rags, sponges, and similar wet cleaning products used in contaminated areas

- Liquid low-level radioactive waste
  - Equipment drains—including, but not limited to, heating, ventilation, and air conditioning systems condensate; mop water from contaminated areas; and emergency shower and eyewash water
  - Decontamination wash water—such as water from decontamination of transportation casks and TAD canisters
  - Floor drain system—collected fire suppression water from potentially contaminated areas

DOE would transport liquid waste to the Low-Level Waste Facility from the Initial Handling Facility, the Canister Receipt and Closure Facilities, the Wet Handling Facility, and the Receipt Facility in tanker trucks or in containers on standard vehicular transport such as an open flatbed truck. The low-level liquid waste would be transferred to a 95-cubic meter (25,000-gallon) liquid low-level waste tank outside the facility adjacent to one of the storage bays. In addition, a 95-cubic meter processed water tank would be outside the facility, adjacent to one of the storage bays. Connections would be provided for offsite bulk shipment.

2.1.2.3.5 *Emergency Diesel Generator Facility*

The Emergency Diesel Generator Facility would be in the central part of the surface geologic repository operations area (Figure 2-5, Facility 26D) and would provide emergency power during the loss of normal electric power. During a power loss, the Emergency Diesel Generator Facility would provide 13.8-kilovolt power to maintain load demands in the waste handling surface facilities. Each of the two emergency diesel generators would operate independently. If normal power failed, the emergency diesel generator would start.

2.1.2.3.6 *Other Balance of Plant Facilities*

This section discusses other balance of plant support facilities outside the geologic repository operations area.

DOE would develop a central operations area approximately 0.8 kilometer (0.5 mile) southwest of the geologic repository operations area for all operations, which would include support and replacement of subsurface infrastructure in the Exploratory Studies Facility. Proposed construction would occur on about 0.12 square kilometer (30 acres) of land that was previously used for equipment and material storage. DOE would construct new support buildings and install utilities (power, water, sewer, and communications). The support buildings would include the following:

- Administration Facility. This facility (Figure 2-5, Facility 620) would include area for offices, training, and computer operations.

- Fire, Rescue and Medical Facility. This multifunctional facility (Figure 2-5, Facility 63A) would provide space and layout for fire protection and firefighting services, underground rescue services, emergency and occupational medical services, and radiation protection. The Helicopter Pad (Figure 2-5, Facility 66A) would provide space for emergency medical evacuation.

- Craft Shops. Craft Shops (Figure 2-5, Facility 71A) would include primary shop services for maintenance and repair operations.

- Vehicle Maintenance and Motor Pool. The Vehicle Maintenance and Motor Pool would be near each other (Figure 2-5, Facility 690). The Vehicle Maintenance and Motor Pool would have space for refueling islands to supply diesel, gasoline, propane, and compressed natural gas to construction vehicles and separate facilities for vehicle maintenance and washing.

- Diesel Fuel Oil Storage and Fueling Station (Figure 2-5, Facilities 70A and 70B, respectively) would provide storage for fuel oil and would be the beginning point of the system that would distribute fuel oil throughout the geologic repository operations area. The fuel-oil system would consist of tanks, pumps, instrumentation, and ancillary equipment. The main fuel-oil storage tank would provide fuel oil to the hot-water boilers and emergency generator primary tanks, as well as standby and emergency generator reserve tanks and diesel-driven fire water pumps.

- Warehouse/Central Receiving. This permanent facility (Figure 2-5, Facility 68A) would consist of storage space, a receiving and shipping dock, and general management functions. These facilities would provide space for material receiving, inspection, and storage; material isolation and control; industrial hazardous materials storage; and management of materials.

Other balance of plant facilities would be the fire water facilities and security stations. There would be four fire water facilities in the surface geologic repository operations area and vicinity when the repository was fully operational (Figure 2-5, Facilities 28A, 28B, 28C, and 28E). The facilities would provide space for fire water storage tanks, pumping equipment and systems, and support equipment.

DOE would establish security stations at personnel access points between the administrative and restricted areas of the geologic repository operations area. These would include two administration security stations, a Central Security Station, a Cask Receipt Security Station, and a North Perimeter Security Station (Figure 2-5, Facilities 65A, 65B, 30A, 30B, and 30C, respectively). The administration security stations would provide space for security functions to control physical access to the general support area. The Central Security Station would provide space for security functions to control physical access to the general management area for repository personnel and equipment. It would establish the primary interfaces between the restricted area and the other areas of the Yucca Mountain site for personnel and vehicle traffic, and would provide security operational functions (such as portal monitors, personnel access control, and vehicle access), as well as internal functions required by or for the security group. The Cask Receipt Security Station would provide facilities for physical inspections (security and radiological) of outgoing casks and incoming cask shipments by either rail or truck. In addition, the Cask Receipt Security Station would function as the point of custody transfer for the receipt of cask shipments. This facility would not support personnel access or egress under normal operating conditions. The North Perimeter Security Station would provide facilities for security functions to control physical access to both the protected and unprotected areas (as defined at 10 CFR 73.2) at the northern perimeter fence in the northeastern portion of the surface geologic repository operations area.

2.1.2.4 Utilities

The proposed utilities for the Yucca Mountain site would include electricity, water supply, wastewater and storm-water systems, Utility Facility and cooling tower, and communications. The following sections discuss each utility.

2.1.2.4.1 *Electrical Power and Distribution*

A new site electrical power system would receive and distribute power to all facilities in the geologic repository operations area and in the vicinity. The electrical power distribution system would include a high-voltage switchyard, a 13.8-kilovolt switchgear facility, an Emergency Diesel Generator Facility with two emergency diesel generators, and a Standby Diesel Generator Facility with four standby diesel generators (Figure 2-5, Facilities 27A, 27B, 26D, and 26B, respectively). The switchyard would provide interface between offsite and onsite electrical power systems.

Two 138-kilovolt transmission lines (with a capability of 230 kilovolts if needed) that originated at the Lathrop Wells switch station or similar locations defined by DOE and the utility supplier would terminate at the main substation, at the switchyard in the proposed central operations area. The transmission lines, which would follow utility corridors parallel to the site access road, could be installed sequentially. As an alternative, one line could follow a utility corridor parallel to the site access road while another line could follow a separate utility corridor as explained in Appendix A. The routing decisions are not solely DOE's but also involve the distributors that supply electric power in the region of influence. From the main substation, the distribution system would branch to several primary electrical distribution points. In addition, a power loop would be installed from the South Portal development area through the main tunnel to the surface geologic repository operations area. Use of this power loop would continue during the *operations period*. For safety purposes, one of the transmission lines could be installed to support current site activity. For analytical purposes, installation of both lines was evaluated during the *construction period*.

2.1.2.4.2 *Water Supply*

The Proposed Action would require both potable and raw, or nonpotable, water systems. The function of the raw water system would be to provide raw water to the North Portal, the North Construction Portal area, and the South Portal. Potable water would be provided to facilities for drinking and for safety fixtures use, such as for emergency showers and eyewashes. Nonpotable water would be provided through the distribution piping as utility water in the nonradiological facilities for washdown and housekeeping. Nonpotable water would also be used in the closed-loop hot water and chilled water systems and for decontamination. Deionized water would be provided for makeup water lost from the pool in the Wet Handling Facility.

Water supply systems would be upgraded, which would include rework of the C-Wells, piping supply systems, water storage tanks, a booster pump station and booster tanks, a fire water tank, chlorination system, arsenic treatment system, a potable water storage tank, service connections to the water system on the North Portal pad, and controls to meet national standards, such as those of the American Water Works Association and National Fire Protection Association. Water storage tanks would be installed in the surface geologic repository operations area or in the immediate vicinity. Water would be pumped from existing C-Wells and J-Wells. A new well at Gate 510 would provide domestic and fire protection water for the Gate 510 security station, off U.S. Highway 95 at the southern entrance of the *land withdrawal area*.

2.1.2.4.3 *Wastewater and Stormwater Systems*

The sanitary waste system would consist of septic tanks and leach fields in the central operations area.

A storm-water collection system would be installed to collect stormwater from roadways, graded areas, and roof surfaces from the waste handling facilities in the vicinity of the North Portal pad and to route this water to an unlined *retention pond* near the Utility Facility (Figure 2-5, Facility 90A). A retention pond is designed to hold a specific amount of water indefinitely.

Three storm-water *detention pond*s in the vicinity of the surface geologic repository operations area would collect storm-water runoff. A detention pond is a low-lying area that is designed to temporarily hold a set amount of water while slowly draining to another location. Such ponds exist for flood control when large amounts of rain could cause flash flooding if not dealt with properly. The detention ponds would be south of the Helicopter Pad and the Cask Receipt Security Station.

During construction or development, DOE would collect excess water from dust-suppression applications and water percolating into the repository drifts, if any, as well as water from tunnel boring operations and water from concrete mixing and cleanup, and pump it to lined *evaporation ponds* at the South Portal development area and the North Construction Portal. An evaporation pond is a containment pond (that should have an impermeable lining of clay or synthetic material) to hold liquid wastes and to concentrate the waste through evaporation. Another evaporation pond (Figure 2-5; Facility 25C) would be near the Utility Facility for collection of blowdown from the cooling tower and liquids from regeneration of water softeners. A fourth evaporation pond would be in the central operations area and would receive process water from two oil-water separators as well as superchlorinated water generated from maintenance of the drinking water system.

While the current design does not specifically include a wastewater treatment facility, DOE could develop one in the future to maximize the use of this resource. Appendix A evaluates the potential benefits and impacts of the implementation of a wastewater treatment facility.

2.1.2.4.4 *Utility Facility and Cooling Tower*

The Utility Facility (Figure 2-5, Facilities 25A, 25B, and 25C, respectively) would include a cooling tower and evaporation pond (described above). The Utility Facility would house the support systems, equipment, and controls, such as those necessary for the heating, ventilation, and air conditioning; central chilled water and hot water heating subsystems; and other services to support process operations, such as chillers, heaters, instrument air, breathing air, and compressed air. Systems in the building that would interface with radiological operations or facilities would be designed with features to prevent radiological cross-contamination of the Utility Facility.

2.1.2.4.5 *Communications Systems*

Expansion and upgrades to the communications systems would include connectivity between the Yucca Mountain site, the Las Vegas Data Center, the DOE Office of Civilian Radioactive Waste Management, management and operating contractor facilities, and Nye County emergency response facilities. This connectivity would consist of dual fiber-optic lines, cellular telephone towers, microwave systems to Las Vegas, radio systems, telephone switch systems, dual satellite links, federally approved encryption equipment, and a network operations building.

2.1.3 CONSTRUCTION SUPPORT FACILITIES

For analytical purposes, DOE has included activities to repair, replace, or improve certain facilities, structures, roads, and utilities (collectively referred to as *infrastructure*) for the Yucca Mountain Project to enhance safety at the project and to enable DOE to safely continue ongoing operations, scientific testing, and routine maintenance as part of the Proposed Action. These activities are assumed to occur during the construction period. These activities would include demolition or relocation of the existing facilities at the North Portal, excavation of fill material down to the original ground contours, and placement and compaction of engineered backfill in the area of waste handling facilities construction. Three concrete batch plants would be in the area. Two plants would have a capacity of 190 cubic meters (250 cubic yards) per hour, and one plant would have a capacity of 115 cubic meters (150 cubic yards) per hour. Aggregate and material storage bins would be collocated with the concrete batch plants.

In addition, the excavated rock currently stored near the North Portal would be removed and either used during construction or moved to an excavated rock storage pile at the South Portal development area. Approximately 600,000 cubic meters (800,000 cubic yards) of fill and excavated rock currently are in the area that would become the surface geologic repository operations area. Improvements would include work at an area previously used for equipment and material storage, about 2.4 kilometers (1.5 miles) southwest of the North Portal. Site preparation of this area would include bringing the site to the appropriate grade, installing underground utilities, improving the entrance, upgrading or constructing access roads and a parking area, and constructing a detention pond.

Development of the Yucca Mountain subsurface facilities would be achieved primarily through the use of two ramps and portals, known as the North Construction Ramp and Portal, at the north end of the repository, and the South Portal development area (which includes a ramp and portal) at the south end of the repository. Figure 2-4 shows the locations of the North Construction Portal and the South Portal. The North Portal would provide access for construction of Panel 1 until receipt of a license to receive and possess radioactive materials.

The North Construction Portal and North Construction Ramp would remain available throughout construction of the repository after emplacement had begun and would allow access for the construction of emplacement panels on the north half of the subsurface facility. In addition, the North Construction Portal and North Construction Ramp would accommodate construction ventilation ducting, ancillary ventilation equipment, and rock removal equipment such as a conveyor. Similar to the North Construction Portal, the South Portal development area would accommodate construction support facilities. In addition, the South Portal development area would support the excavation and construction of the repository and occupy about 0.08 square kilometer (20 acres).

Both the North Construction Portal and the South Portal development area would contain:

- Staging facilities for personnel, materials, and equipment.
- Concrete batch plants.
- Equipment maintenance facilities that included wash racks and a change house.
- Excavated rock storage areas. Under the current design, two separate locations are designated for the storage of excavated rock. Excavated rock initially would be removed from the South Portal and placed in a storage area near the South Portal development area. The remainder of the excavated rock would be removed from the North Construction Portal and placed in a rock storage area north of the aging pads and east of the North Construction Portal. The area covered by both excavated rock storage areas would be approximately 0.8 square kilometer (200 acres).
- Utilities services, including electricity, water, and wastewater disposal to a septic tank and leach field.

2.1.4 OTHER PROJECT FACILITIES

This section discusses other project facilities that would support the construction, operation, monitoring, and eventual closure of the repository. With the exception of onsite roads and the surface facilities for the performance confirmation activities, these facilities would be outside the geologic repository operations area.

2.1.4.1 Roads

DOE would construct, improve, or replace paved roads and graded dirt construction and haul roads in the land withdrawal area. In addition, DOE would build (1) a new 13.7-kilometer (8.5-mile)-long, four-lane, paved access road from a point 3.7 kilometers (2.3 miles) north of Gate 510 on the existing access road of the Nevada Test Site to a point about 0.8 kilometer (0.5 mile) east of Fortymile Wash, where it would connect to an existing road (H Road), (2) a new 2.1-kilometer (1.3-mile)-long, two-lane, paved road to the crest of Yucca Mountain, and (3) a new 4-kilometer (2.5-mile)-long road leading to Fran Ridge. In total, DOE would construct about 40 kilometers (25 miles) of paved roads (new and replacement roads) within the *Yucca Mountain site boundary* (Figure 2-10).

In addition, DOE would construct a four-lane access road that would extend from U.S. Highway 95 to the existing access road at Gate 510. This access road could be constructed with the use of a phased approach, with initial construction of two lanes, and later widening of the road. A suitable intersection at U.S. Highway 95 also would be constructed.

2.1.4.2 Engineering and Safety Demonstration Facility

The Department would construct an Engineering and Safety Demonstration Facility in the land withdrawal area, approximately 3.2 kilometers (2.0 miles) southeast of the South Portal, at Fran Ridge. Its primary mission would be to provide data for health and safety, engineering, construction, and operations, and as a location for public outreach. The Engineering and Safety Demonstration Facility would demonstrate the following:

- The feasibility of certain features of the design and operation of a repository (for example, emplacement of ground support, waste packages, drip shields, and demonstration of dust and noise control and monitoring techniques);

- Repository constructability (for example, excavation of turnouts, keyways, drill-and-blast performance) in different types of rock, excavation of emplacement drifts by different techniques, installation of drip shields, and installation of high-density ballast for emplacement invert; and

- Remote systems (for example, a transport and emplacement vehicle for emplacement and retrieval of waste packages).

The Engineering and Safety Demonstration Facility would require construction of a 3.7-kilometer (2.3-mile)-long, 7.6-meter (25-foot)-diameter tunnel beneath Fran Ridge. The tunnel would be excavated by drilling, blasting, and mechanical techniques. About 150,000 cubic meters (200,000 cubic yards) of rock would be excavated and stored near the South Portal development area. A 138-kilovolt power line would branch off the proposed power line for the repository and extend about 4 kilometers (2.5 miles) southward to a proposed substation at Fran Ridge. The power, water, and sewage needs of the Engineering and Safety Demonstration Facility would be met by connection to the onsite infrastructure, which would already exist to support construction and operation of the repository.

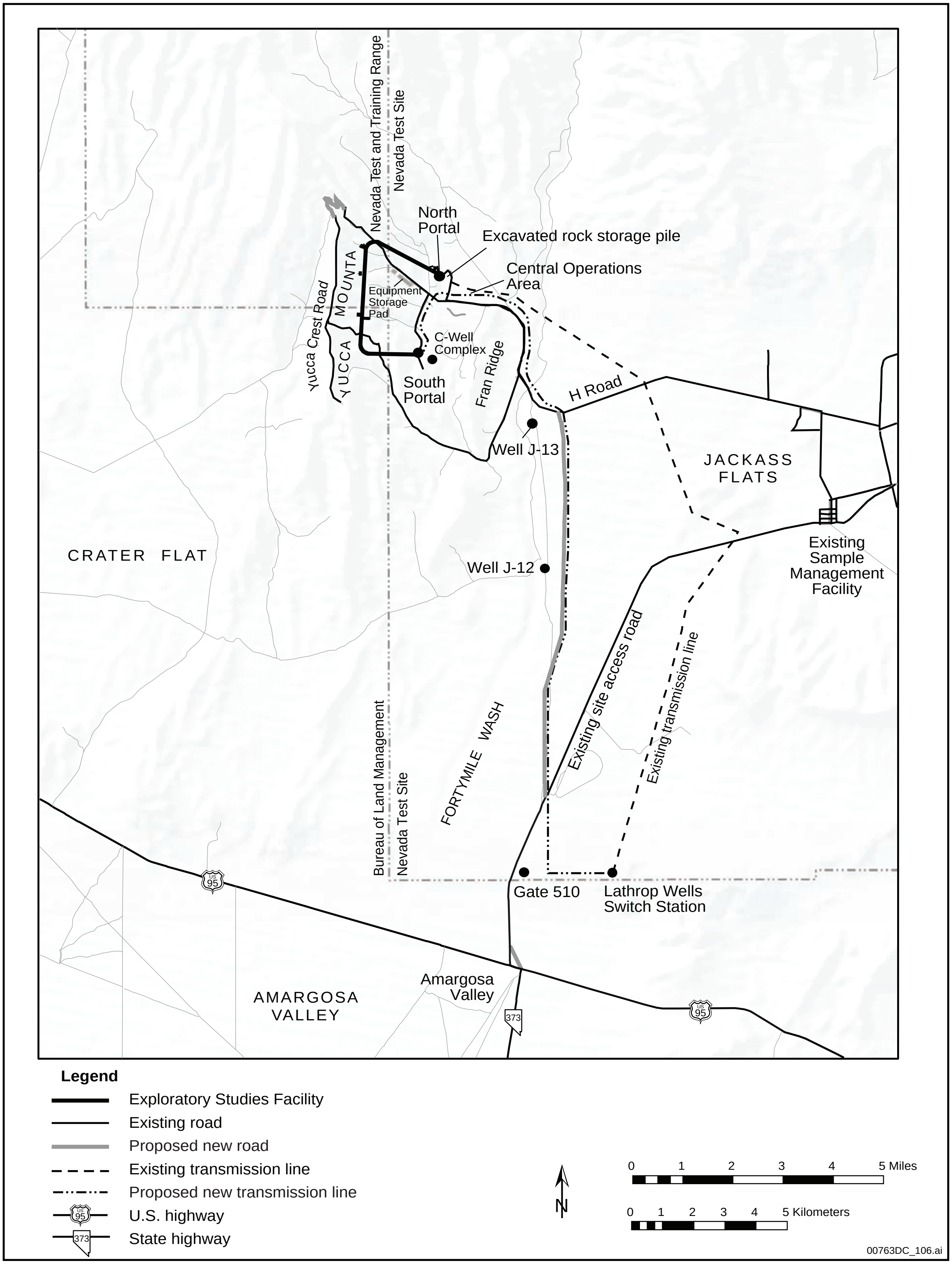


Figure 2-10. Location of features in the vicinity of the Yucca Mountain site.

2.1.4.3 Offsite Training Facility

DOE would construct a training facility near the Yucca Mountain site to support the Project Prototype Testing and the Operator Training and Qualification programs. The facility would not be in the land withdrawal area. DOE has assumed a location near Gate 510 for the environmental impact analysis in this Repository SEIS.

2.1.4.4 Temporary Accommodations

Temporary accommodations for construction workers could be required to support expedited construction of the repository. They would include housing for construction workers; a utility zone dedicated to power supply, temporary trash storage, wastewater, and potable water treatment; eating facilities; laundry facilities; and office space. The temporary accommodations would be prepared by clearing, hauling of gravel fill, leveling, and compaction. Roads and parking areas would be created with gravel fill. Lighting would be installed for security and parking. Utility services would be provided by commercial sources. The accommodations could be expanded as necessary for additional personnel. They would be removed when no longer needed. For a conservative analysis, DOE has assumed a location near Gate 510 for the environmental impact analysis in this Repository SEIS. However, DOE could use the temporary accommodations for railroad construction workers planned for the Crater Flat area as part of the proposal in the Rail Alignment EIS. Depending on the need for housing, the Department could use the rail construction camp either in lieu of temporary accommodations at the southern boundary or in addition to those accommodations.

2.1.4.5 Sample Management Facility

DOE would construct a proposed Sample Management Facility to consolidate, upgrade, and improve storage and warehousing for scientific samples and materials. The facility could be inside the land withdrawal area, but for a more conservative analysis, DOE assumed it would be outside the land withdrawal area near Gate 510. This facility would house a variety of samples collected from studies, including rock cores. The building area would be about 3,900 square meters (42,000 square feet), surrounded by a 3,300-square-meter (36,000-square-foot) fenced area.

2.1.4.6 Surface Facilities for Performance Confirmation Activities

DOE would build surface facilities to support performance confirmation activities. These facilities would be used for administrative functions, test equipment repair and calibration, remote-operated vehicle maintenance, and data acquisition and communications.

2.1.4.7 Marshalling Yard and Warehouse

This proposed leased facility would consolidate material shipment and receipt into one 0.2-square-kilometer (50-acre) facility outside the land withdrawal area to enable offsite receipt, transfer, and staging of materials for construction activities at the Yucca Mountain site. Material would be hauled to the site on a just-in-time basis. The marshalling yard would require some fencing, offices, warehousing, open laydown, and shops. Some prefabrication, assembly, and other light industrial activities could be performed at this location. DOE has assumed a location near Gate 510 for environmental impact analysis in this Repository SEIS.

2.1.4.8 Borrow Pits

DOE has not determined the location for the source of aggregate and fill material for building the repository and surface facilities. For the analysis in this Repository SEIS, DOE assumed the location is in the land withdrawal area; land disturbance would be approximately 0.4 square kilometer (100 acres).

2.1.4.9 Explosives Storage Area

DOE would store explosives in accordance with programs developed under 10 CFR Part 851, considering requirements similar to those of the Bureau of Alcohol, Tobacco and Firearms regulations (27 CFR Part 555) and Occupational Safety and Health Administration Standards (29 CFR 1910.109). DOE would build a permanent Class I magazine for the storage of high explosives. A magazine is any building or structure, other than an explosives manufacturing building, for the storage of explosives. A Class I magazine would be required because DOE would probably store more than 22.7 kilograms (50 pounds) of explosives at any one time. The regulations at 29 CFR 1910.109 specify requirements for a Class I magazine, including but not limited to distance from other magazines, posting with signs, construction material type, and ventilation.

2.1.4.10 Solid Waste Landfill

DOE would construct a State-permitted solid waste landfill on the Yucca Mountain site for disposal of industrial waste, including construction and demolition debris, and sanitary waste. DOE has not yet determined the location for the landfill.

2.1.5 PERFORMANCE CONFIRMATION PROGRAM

Performance confirmation refers to the program of tests, experiments, and analyses that DOE would conduct to evaluate the adequacy of the information used to demonstrate compliance with the performance objectives at 10 CFR Part 63, Subpart F. Specifically, the Performance Confirmation Program must provide data that indicate, where practicable, (1) actual subsurface conditions and changes in those conditions during construction, and waste emplacement operations are within the limits assumed in the licensing review, and (2) natural and engineered systems and components that are required for repository operation and that are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

The Yucca Mountain Performance Confirmation Program began during *site characterization* and would continue until permanent closure of the repository, in accordance with 10 CFR 63.131(b). The Performance Confirmation Program would include elements of site testing, repository testing, repository support facilities construction, and waste package testing. If the NRC granted the license for construction authorization, the activities would focus on monitoring and data collection for performance parameters important to the terms and conditions of the license.

The Performance Confirmation Program would monitor repository conditions and perform tests to confirm geotechnical and design assumptions. The repository design and emplacement operations would preserve the ability to retrieve any or all waste packages before closure of the repository in accordance with 10 CFR 63.111(e). Retrieval, as defined at 10 CFR 63.2, would be the act of permanent removal of radioactive waste from the subsurface location at which the waste had been previously emplaced for disposal. Section 4.2 of this Repository SEIS discusses implementation of a retrieval contingency and the associated environmental impacts.

A performance confirmation observation drift would be built about 15.2 meters (50 feet) below one of the emplacement drifts in the first panel. DOE would drill boreholes from the performance confirmation observation drift that would approach the rock mass near the emplacement drift; instruments in these boreholes would gather data on the thermal, mechanical, hydrological, and chemical characteristics of the rock after waste emplacement. DOE would acquire performance confirmation data from instruments in the performance confirmation drift or along the perimeter mains through remote inspections in emplacement drifts and monitoring of ventilation exhaust and water quality in wells.

Confirmatory data about anticipated postclosure conditions in the repository would be obtained during the preclosure period using thermally accelerated drifts. The intent would be to develop thermal environments in emplacement drifts in which representative postclosure coupled thermal, hydrologic, mechanical, chemical, microbial, and radiological processes and effects could be monitored or observed. Activities planned in thermally accelerated drifts would monitor in-drift conditions, expose engineered barrier material samples to potential corrosion mechanisms in representative *in situ* environments, monitor drift degradation, and test near-field coupled processes. The thermally accelerated drift conceptual design includes at least one thermally accelerated drift at the repository horizon and an observation and instrumentation drift at a lower elevation.

DOE would use the Performance Confirmation Program data to evaluate system performance and predict system response. If the data indicated that actual conditions differed from the predictions, DOE would notify the NRC and undertake remedial actions to address any such condition. The current repository design includes features to implement the Performance Confirmation Program.

2.1.6 REPOSITORY CLOSURE

Before closure, DOE would submit an application to amend the NRC license to receive and possess waste. The application would provide an update of the assessment of repository performance for the period after closure, as well as a description of the program for postclosure monitoring to regulate or prevent activities that could impair the long-term isolation of waste. The Postclosure Monitoring Program, as required by Section 801(c) of the *Energy Policy Act of 1992* and as required by the NRC (10 CFR Part 63), would include the monitoring activities that DOE would conduct around the repository after it closed and sealed the facility. Regulations at 10 CFR 63.51(a)(1) and (2) require the submittal of a license amendment for closure of the repository. The details of this program would be delineated during processing of the license amendment for closure. Deferring the delineation of this program to the closure phase would allow identification of appropriate technology, which would include technology that might not be currently available.

The closure period would last 10 years. Closure of the repository would include the emplacement of the drip shields; removal and salvage of equipment and materials; backfilling; and sealing of subsurface-to-surface openings. Backfilling would require surface operations to obtain fill material from the excavated rock storage area or another source, and processing (screening, crushing, and possibly washing) the material to obtain the required characteristics. Fill material would be transported on the surface in trucks and subsurface in open gondola railcars. A fill-placement system would place the material in the subsurface ramps. DOE would place the seals for shafts, ramps, and boreholes strategically to reduce *radionuclide* migration over extended periods, so these openings could not become pathways that could compromise the repository's postclosure performance.

Surface facilities would be decontaminated, if required, and dismantled. Equipment and materials would be salvaged, recycled, or reused, if possible. Reclamation would include restoration of the site to as near its preconstruction condition as practicable, which would include the recontouring of disturbed surface areas, surface backfill, soil buildup and reconditioning, site revegetation, site water course configuration, and erosion control, as appropriate.

In compliance with 10 CFR Part 63, DOE would erect a network of permanent monuments and markers around the site to warn future generations of the presence and nature of the buried waste, and detailed public records would identify the location and layout of the repository and the nature and hazard of the waste it contains. The Federal Government would maintain *institutional control* of the site. Active and passive security systems and monitoring would prevent deliberate or inadvertent human intrusion and any other human activity that could adversely affect the repository.

2.1.7 TRANSPORTATION ACTIVITIES

Under the Proposed Action, DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository. The Naval Nuclear Propulsion Program would transport *naval spent nuclear fuel* from the Idaho National Laboratory to the repository. Section 2.1.7.1 discusses loading activities of these materials at generator sites. Sections 2.1.7.2 and 2.1.7.3 discuss transportation of the materials to the Yucca Mountain site, across the nation and in Nevada, respectively. Chapter 6 and Appendix G of this Repository SEIS provide further discussion of transportation activities and resultant environmental impacts.

2.1.7.1 Loading Activities at Commercial and DOE Sites

The Proposed Action in this Repository SEIS includes the shipping of empty casks and TAD canisters to commercial and DOE sites, as well as loading of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites for transportation to Yucca Mountain. Loading activities would include preparing the spent nuclear fuel or high-level radioactive waste for shipment, loading it into a transportation cask, and placing the transportation cask on a vehicle. Other activities would include the loading of commercial spent nuclear fuel into TAD canisters and the subsequent loading of TAD canisters into transportation casks. This Repository SEIS assumes that at the time of shipment, the spent nuclear fuel and high-level radioactive waste would be in a form that met approved acceptance and disposal criteria for the repository.

2.1.7.2 National Transportation

Under the Proposed Action evaluated in this Repository SEIS, DOE would transport spent nuclear fuel and high-level radioactive waste from 76 sites across the country to the repository by mostly rail. Some spent nuclear fuel and high-level radioactive waste would be transported by truck. Figures 2-11 and 2-12 show the representative national rail and truck routes, respectively, evaluated in this Repository SEIS.

For this Repository SEIS, DOE has updated the routes to reflect the current highway and rail routes in the United States and to add routes that support the Mina Corridor that DOE considers in the Rail Alignment EIS. Representative routes are routes that were analyzed but might not be the routes actually used for

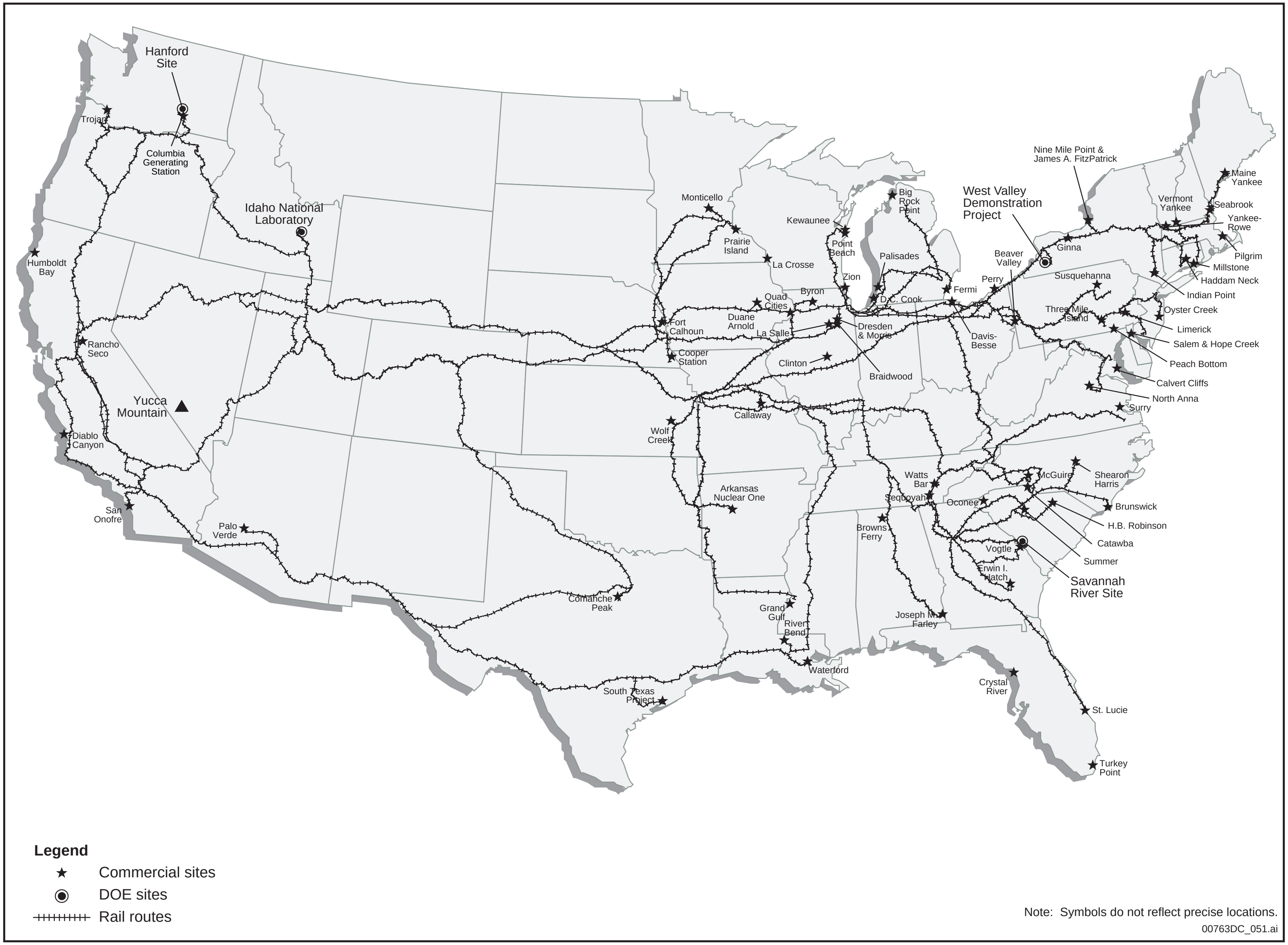


Figure 2-11. Representative national rail routes considered in the analysis for this Repository SEIS.

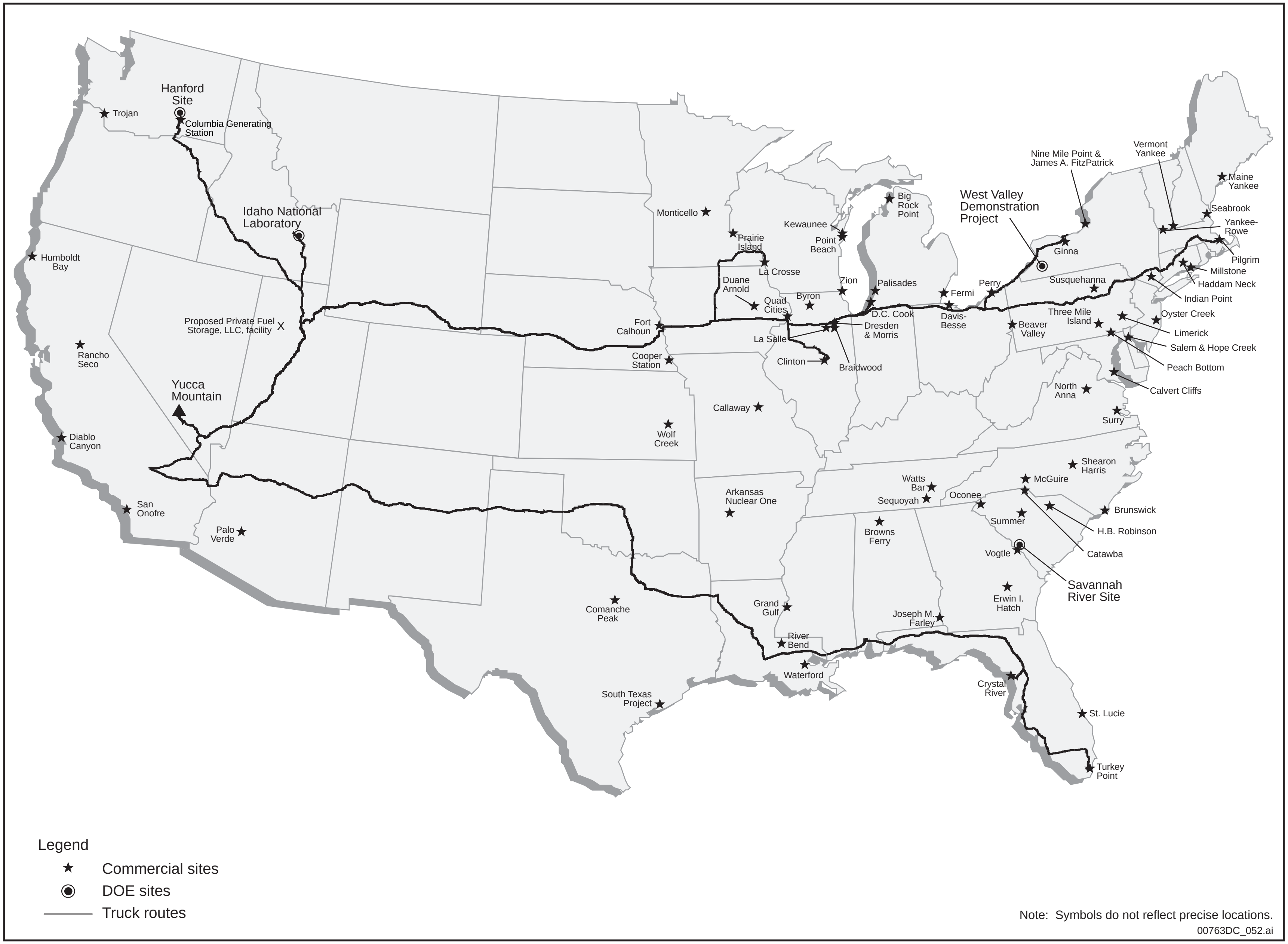


Figure 2-12. Representative national truck routes evaluated in this Repository SEIS .

shipment to the repository. Rail routes are based on maximizing the use of mainline track and minimizing the overall distance and number of interchanges between railroads.

Important elements of DOE's national transportation plan that have evolved since publication of the Yucca Mountain FEIS include the following:

- DOE has established the policy to use dedicated trains for shipments of commercial and DOE spent nuclear fuel and high-level radioactive waste. This policy would not apply to shipments of naval spent nuclear fuel. For shipments of commercial and DOE spent nuclear fuel and high-level radioactive waste, there would be from one to five casks that contained spent nuclear fuel or high-level radioactive waste per train. For shipments of naval spent nuclear fuel, this analysis assumed regular freight service and from 1 to 12 casks that contained spent nuclear fuel per train. In both cases, two buffer cars, two to three locomotives, and one to two escort cars would be present. A buffer car is a flatbed railcar that would be at the front of a cask train between the locomotive and the first cask car and at the back of the train between the last cask car and the escort car. An escort car is a railcar in which escort personnel would travel on trains that carried spent nuclear fuel or high-level radioactive waste.

- Trucks that carried transportation casks could be overweight rather than legal weight. These *overweight trucks* would be subject to the additional permitting requirements in each state through which they traveled.

- This Repository SEIS evaluates transportation of spent nuclear fuel and high-level radioactive waste from 72 commercial sites and 4 DOE sites, for a total of 76 locations (one less than in the Yucca Mountain FEIS because DOE will ship spent nuclear fuel currently stored at Fort St. Vrain, Colorado, to the Idaho National Laboratory for packaging and then to the repository). This Repository SEIS analyzes the shipment of approximately 9,500 rail casks and 2,700 truck casks of spent nuclear fuel and high-level radioactive waste. The Yucca Mountain FEIS analyzed approximately 9,600 rail casks and 1,100 truck casks under the mostly rail shipping scenario. The estimated number of truck and rail casks changed primarily due to the use of TAD canisters and revised information on interface capabilities and cask handling capabilities at U.S. nuclear facilities.

- Based on interim compensatory measures now required by the NRC that DOE would follow, at least two security escorts would be present in all areas (urban, suburban, and rural) during the shipment of spent nuclear fuel and high-level radioactive waste.

2.1.7.3 Nevada Transportation

Concurrent with this Repository SEIS, DOE has prepared the Nevada Rail Corridor SEIS and the Rail Alignment EIS to make further transportation decisions in the State of Nevada. In the Nevada Rail Corridor SEIS, DOE considered the feasibility and environmental impact of using the Mina rail corridor, which it had excluded from consideration in the Yucca Mountain FEIS, as explained in the Foreword of this Repository SEIS. In addition, DOE updated environmental information for three other rail corridors considered in the Yucca Mountain FEIS, specifically the Carlin, Jean, and Valley Modified Corridors. DOE examined both the Mina and Caliente rail corridors at the alignment level in the Rail Alignment EIS. DOE had selected the Caliente rail corridor in its April 8, 2004, Record of Decision (69 FR 18557).

To serve as a complete supplement to the Yucca Mountain FEIS, this Repository SEIS includes the impacts of transportation of spent nuclear fuel and high-level radioactive waste to the repository under the mostly rail scenario, with the rail shipments occurring in either the Caliente or Mina rail corridor (Figure 2-13) by incorporating the Rail Alignment EIS by summary and reference into all applicable chapters of this document. The Foreword of this document describes the integration of the results of the Rail Alignment EIS.

Under the Proposed Action in the Rail Alignment EIS, DOE analyzes specific potential impacts of constructing and operating a rail line along common segments and alternative segments within the Caliente and Mina Corridors for the purpose of determining an alignment in which to construct and operate a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to a geologic repository at Yucca Mountain. This Repository SEIS uses information from the Rail Alignment EIS to identify all impacts associated with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. To aggregate potential impacts associated with transportation of spent nuclear fuel and high-level radioactive waste to the repository, this Repository SEIS summarizes and incorporates by reference those portions of the Rail Alignment EIS necessary to understand the impacts associated with construction and operation of a railroad in Nevada, including cumulative impacts. This Repository SEIS provides direction to those portions of the Rail Alignment EIS that do not deal directly with the aggregation of impacts that would be associated with the SEIS Proposed Action. The following sections summarize the Proposed Action that DOE examines in the Rail Alignment EIS.

2.1.7.3.1 *Summary of the Proposed Action in the Rail Alignment EIS*

In the Rail Alignment EIS, DOE analyzes a Proposed Action and a No-Action Alternative. The Proposed Action is to determine an alignment (within a corridor) and construct, operate, and potentially abandon a railroad in Nevada to transport spent nuclear fuel, high-level radioactive waste, and other Yucca Mountain project materials to a repository at Yucca Mountain. There are two implementing alternatives under the Proposed Action – the Caliente Implementing Alternative, under which the Department would construct the proposed railroad in the Caliente rail corridor, and the Mina Implementing Alternative, under which the Department would construct the proposed railroad in the Mina rail corridor. The Caliente Implementing Alternative is DOE’s preferred alternative. The Mina Implementing Alternative is a nonpreferred alternative.

In the Rail Alignment EIS, DOE considers a series of *common segments* and a range of *alternative segments* during development of the Proposed Action. The identified alternative rail segments are a subset of the Proposed Action and are not standalone alternatives. The Rail Alignment EIS compares and contrasts the alternative segments and identifies the preferred alternative segments. In addition, the Rail Alignment EIS identifies segments that DOE has eliminated from detailed analysis.

Under the Proposed Action, the proposed railroad would be dedicated to DOE transport of spent nuclear fuel, high-level radioactive waste, and other Yucca Mountain project materials. However, for each implementing alternative in the Rail Alignment EIS, DOE analyzed a shared-use option under which the Department would allow commercial shippers to use the rail line for general freight shipments. General freight would include stone and other nonmetallic minerals, petrochemicals, nonradioactive waste materials, or other commodities that private companies would ship or receive.

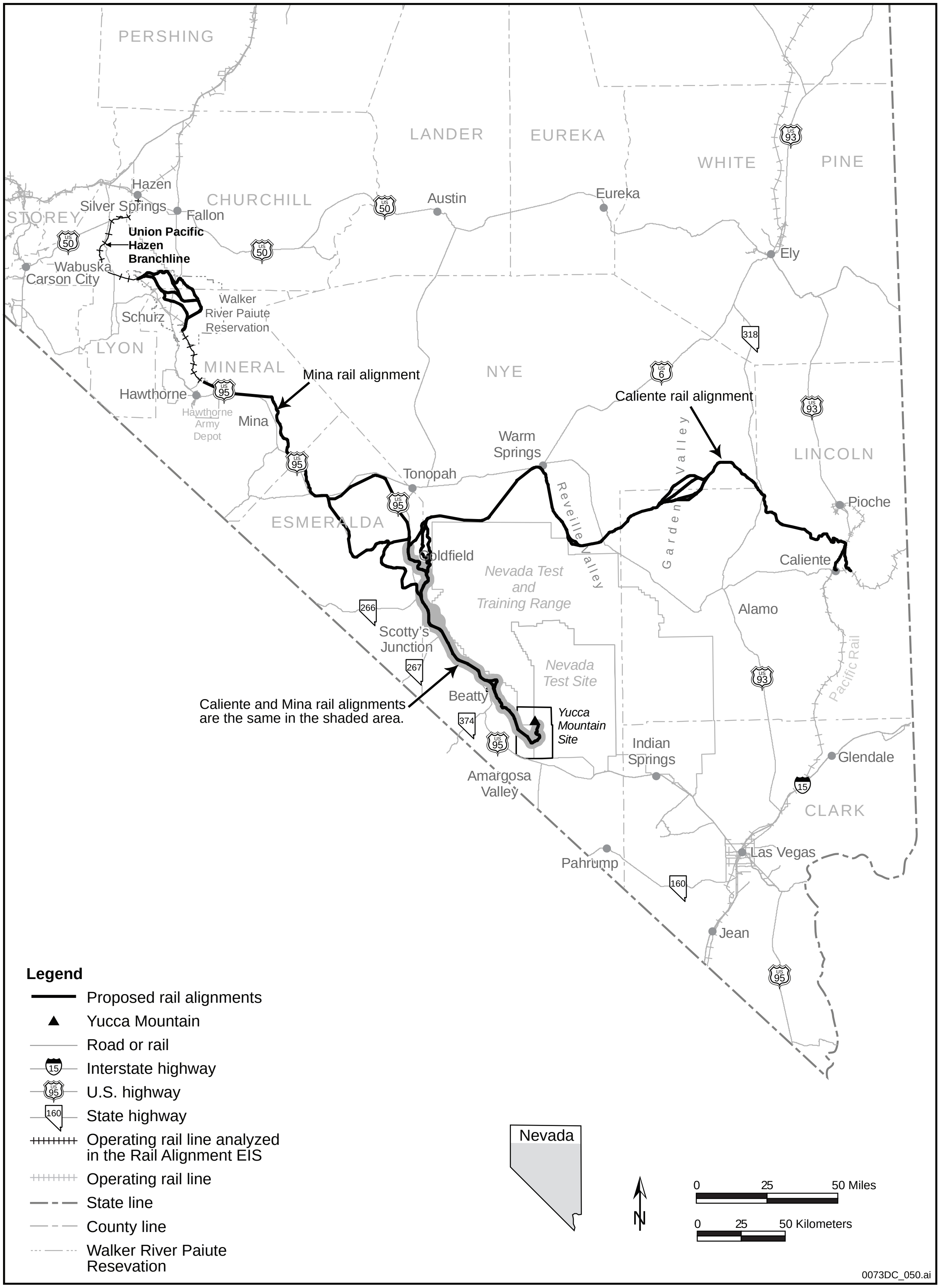


Figure 2-13. Caliente and Mina rail alignments

DOE would use the rail line primarily to ship approximately 9,500 casks containing spent nuclear fuel and high-level radioactive waste from either the Caliente or Hawthorne area (the town where construction of the new rail line would begin in the Caliente or Mina Corridor, respectively) to the repository over a 50-year operations period. DOE also would ship approximately 29,000 railcars of other materials, which would include repository construction materials, materials necessary for day-to-day operations of the rail line and the repository, and waste materials for disposal, such as scrap metal and solid waste.

The Proposed Action includes the construction and operation of several facilities that would be necessary for the operation of the rail line. These facilities would include the Railroad Staging Yard, the Interchange Yard (Caliente Implementing Alternative), the Maintenance-of-Way Facilities, the Rail Equipment Maintenance Yard, the Cask Maintenance Facility, and the Nevada Railroad Control Center and National Transportation Operations Center. DOE would construct these facilities at the same time it constructed the rail line and would coordinate facility construction with rail line construction.

Under the No-Action Alternative in the Rail Alignment EIS, DOE would not implement the Proposed Action in the Caliente rail corridor or the Mina rail corridor. DOE would relinquish the public lands withdrawn from surface entry and the location of new mining claims for purposes of evaluating the lands for the potential construction, operation, and maintenance of a rail line. These lands would then become available for other uses as determined by the Bureau of Land Management once it amended or revoked the withdrawal. In the event that DOE did not select a rail alignment in the Caliente or Mina rail corridor, the future course that it would pursue is uncertain.

Chapter 6 of this Repository SEIS summarizes the impacts of the alternatives presented in the Rail Alignment EIS and incorporates them by reference.

2.1.7.3.2 *Rail Equipment Maintenance Yard and the Repository Interface*

The railroad would approach Yucca Mountain from east of U.S. Highway 95, trending generally southeast for 40 kilometers (25 miles) from Oasis Valley to Beatty Wash. It would then turn north at the southern end of Busted Butte, running west of Fran Ridge and then trending generally north for an additional 11 kilometers (7 miles) until terminating at the Rail Equipment Maintenance Yard inside the Yucca Mountain Site boundary and about 1.6 kilometers (1 mile) south of the southern boundary of the geologic repository operations area (Figure 2-14). The geologic repository operations area interface would consist of a double-track spur that led into the surface geologic repository operations area for delivery of casks and supplies to the repository.

This area would include a Satellite Maintenance-of-Way Facility, a Locomotive and Car Light Repair Facility, and an escort car service facility, and it could serve as the location of the Cask Maintenance Facility, the Railroad Control Center, and the National Transportation Operations Center.

The Rail Equipment Maintenance Yard would include a shop for washing, inspection, and repair of locomotives and railcars; communications equipment; and housing for train crews and escort personnel (in the same building as the Railroad Control Center and National Transportation Operations Center if they were at the Rail Equipment Maintenance Yard). The facility would be on a 0.41-square-kilometer (100-acre) site.

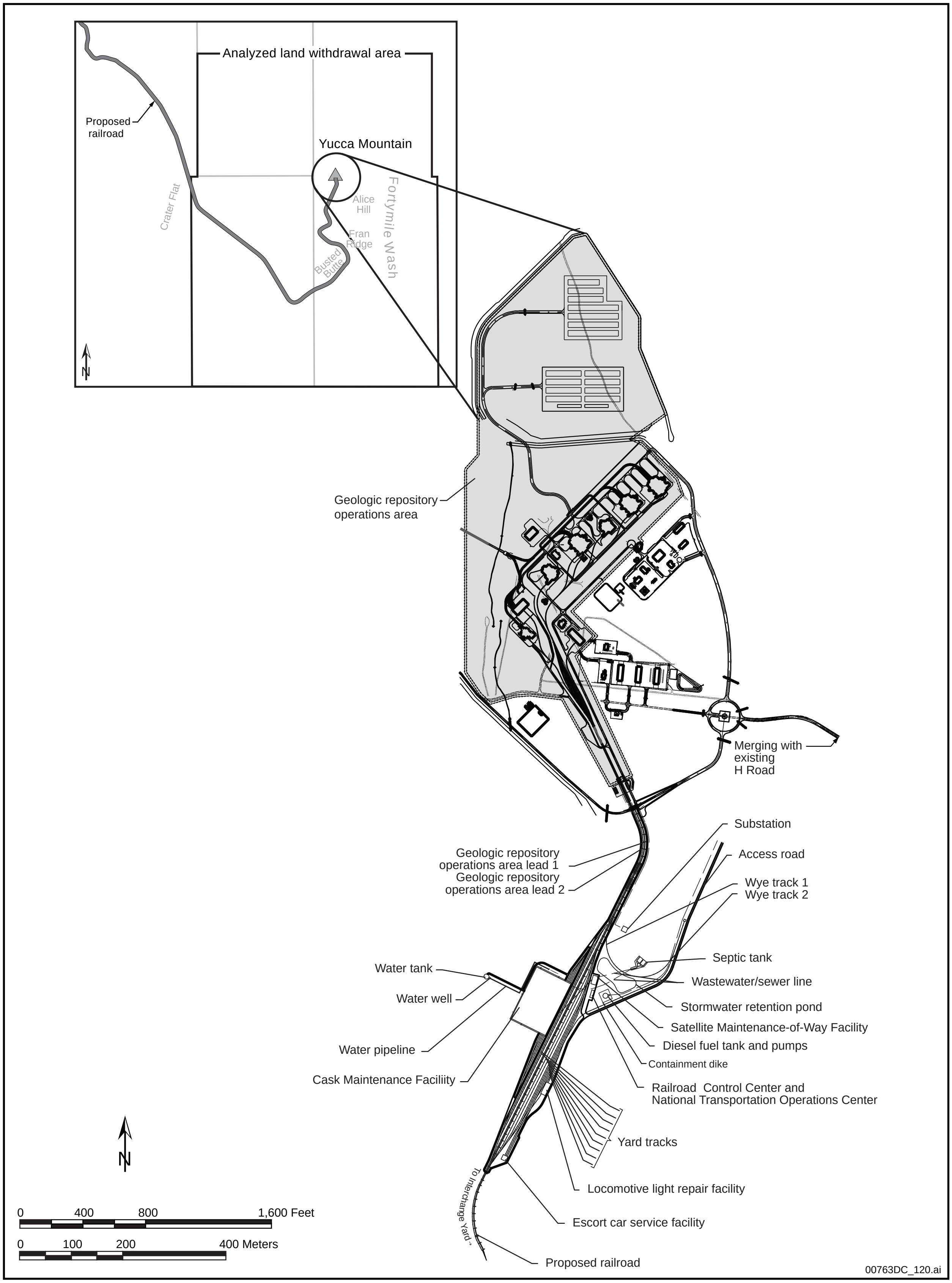


Figure 2-14. The Rail Equipment Maintenance Yard interface at the geologic repository operations area.

2.1.7.3.3 *Cask Maintenance Facility*

The primary purpose of the Cask Maintenance Facility would be to process transportation casks and to ensure that all casks were road-ready and configured with the correct equipment. The basic functions of the facility would be those necessary to ensure compliance with an NRC-issued Certificate of Compliance.

For the purposes of analysis in this Repository SEIS, the Cask Maintenance Facility would be at the Rail Equipment Maintenance Yard. This location would enable the facility to service the casks before their return to the commercial or DOE sites. However, the Cask Maintenance Facility could be along any portion of the Caliente rail alignment between Caliente and the Yucca Mountain site boundary or any portion of the Mina rail alignment between Hawthorne and the Yucca Mountain site boundary or outside the State of Nevada. The Cask Maintenance Facility would require about 0.08 square kilometers (20 acres).

2.2 No-Action Alternative

This section summarizes and incorporates by reference Section 2.2 of the Yucca Mountain FEIS.

The No-Action Alternative provides a basis for comparison with the Proposed Action. Under the No-Action Alternative, and consistent with Section 113(c)(3) of the *Nuclear Waste Policy Act*, as amended, DOE would curtail activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. Commercial nuclear power utilities and DOE would continue to manage the 76 identified generator sites under one of the following two scenarios. Under No-Action Scenario 1, long-term storage of the spent nuclear fuel and high-level radioactive waste would occur at the current storage sites with effective *institutional control* for at least 10,000 years. Under institutional control, these facilities would be maintained to ensure that workers and the public were protected in accordance with current federal regulations. The storage facilities would be replaced every 100 years under Scenario 1. Under No-Action Scenario 2, long-term storage of the spent nuclear fuel and high-level radioactive waste would occur at the current storage sites with no effective institutional control after about 100 years. Beyond that time, the scenario assumes no institutional control. Therefore, after about 100 years and up to 10,000 years, the analysis assumes that the spent nuclear fuel and high-level radioactive waste storage facilities at commercial and DOE sites would begin to deteriorate and that the radioactive materials in them could eventually escape to the environment. DOE used a regional approach that divided the continental United States into five regions to analyze the No-Action Alternative. In the Yucca Mountain FEIS, DOE recognized that the future course Congress, DOE, and the commercial utilities would take, if Yucca Mountain was not approved, is uncertain. A number of possibilities could be pursued, including continued storage at existing sites or at one or more centralized locations, study and selection of another location for a geologic repository, the development of new technologies, or reconsideration of alternatives to geologic disposal. The Yucca Mountain FEIS listed representative studies on centralized or regionalized interim storage and summarized relevant environmental considerations. However, because of these uncertainties, DOE decided to illustrate the range of potential environmental impacts by analyzing the aforementioned two scenarios.

While the No-Action Alternative has not changed, DOE has recognized the State of Nevada's concerns about the No-Action Alternative expressed during scoping meetings by reconsidering the validity of the No-Action Alternative's analytical scenarios in this Repository SEIS. DOE has elaborated on the uncertainties, and thus unpredictability, of future actions in the event the Proposed Action for Yucca Mountain is not approved. This discussion is found in Chapter 7 of this Repository SEIS.

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

This section summarizes the potential impacts of the Proposed Action and the No-Action Alternative. For the Proposed Action, this summary includes preclosure impacts and postclosure impacts for the proposed repository as well as those from transportation both nationally and in the State of Nevada. *Preclosure impacts* are those that would occur during the construction, operation and monitoring, and eventual closure of the proposed repository; *postclosure impacts* are those that would occur after permanent repository closure, for which DOE analyzed impacts for the first 10,000 years and the post-10,000-year period (up to 1 million years). This section updates the information in the Yucca Mountain FEIS and incorporates relevant new information or new environmental considerations.

DOE has characterized potential impacts in this Repository SEIS as *direct* or *indirect*. A direct impact is an effect that would result solely from the Proposed Action without intermediate steps or processes. Examples include habitat destruction, soil disturbance, air emissions, and water use. An indirect impact is an effect that would be related to but removed from the Proposed Action by an intermediate step or process. Examples include surface-water quality changes from soil erosion at construction sites, reductions in productivity from changes in soil temperature, and job growth due to repository employment.

DOE has quantified impacts where possible; additionally, the Department has provided qualitative assessments with these descriptors:

- *Small*. Environmental effects would not be detectable or would be so minor that they would not destabilize or noticeably alter any important attribute of the resource.
- *Moderate*. Environmental effects would noticeably alter but not destabilize important attributes.
- *Large*. Environmental effects would be clearly noticeable and would destabilize important attributes.

This summary and comparison of the Proposed Action and No-Action Alternative impacts is based on the impact analyses in the following chapters of this Repository SEIS:

- Chapter 4 describes potential preclosure environmental impacts during construction, operation and monitoring, and closure of the repository and includes those from the manufacture of waste packages, TAD canisters, and shipping casks.
- Chapter 5 describes the potential postclosure environmental impacts from the disposal of spent nuclear fuel and high-level radioactive waste in the repository.
- Chapter 6 describes the potential impacts of the transportation of spent nuclear fuel, high-level radioactive waste, other materials, and personnel to and from the repository. It includes the impacts of construction and operation of a railroad in Nevada, which DOE presents in more detail in the Rail Alignment EIS.

- Chapter 7 describes the potential impacts of the No-Action Alternative.

- Chapter 8 describes potential cumulative impacts in relation to other activities in the regions of influence.

Section 2.3.1 summarizes the potential preclosure and postclosure impacts of the proposed repository. Section 2.3.2 summarizes the potential impacts of national and Nevada transportation. Section 2.3.3 summarizes the potential impacts of the No Action Alternative. Section 2.3.4 combines, and adds together where possible, the impacts from the repository and transportation analyses to present the total estimated impacts of the Proposed Action. It identifies where the regions of influence overlap for this Repository SEIS and the Rail Alignment EIS and describes impacts in those overlap areas.

2.3.1 POTENTIAL PRECLOSURE AND POSTCLOSURE IMPACTS OF REPOSITORY CONSTRUCTION, OPERATIONS, MONITORING, AND CLOSURE

DOE analyzed preclosure impacts for the proposed repository in four analytical periods—construction, operations, monitoring, and closure—for 13 resource areas and included impacts from the two connected actions, manufacturing repository components and airspace restrictions. (Chapter 4). In this Repository SEIS, DOE used the current repository design and operational plans as the analytical basis for evaluation of repository impacts.

Table 2-2 summarizes preclosure impacts from the repository construction, operations, monitoring, and closure analytical periods. The table identifies the sections of this Repository SEIS that contain more information about the impacts.

For postclosure impacts, DOE assessed the potential impacts from the release of radiological and nonradiological hazardous materials over much longer periods (the first 10,000 years and the post-10,000-year period) after the permanent closure of the repository (Chapter 5). The Department based these projections on the best available scientific techniques and focused the assessment of postclosure impacts on human health, biological resources, and surface- and groundwater resources. The analysis led to the following conclusions:

- There could be very low levels of contamination in the groundwater in the *Amargosa Desert* for a long period.

- The proposed repository would release radionuclides over a long period of time. The analysis demonstrated that the postclosure performance of the proposed repository over the first 10,000 years would result in a mean and median annual individual dose that would not exceed 0.24 millirem and 0.12 millirem, respectively, to a reasonably maximally exposed individual (RMEI) hypothetically located 18 kilometers (11 miles) from the repository. The analysis of the post-10,000-year period resulted in a mean and median annual individual dose that would not exceed 2.3 millirem and 0.98 millirem, respectively, to the RMEI at the same location. There would be no adverse health effects to individuals from these projected doses.

Table 2-2. Potential preclosure and postclosure impacts from repository construction, operations, monitoring, and closure.

Resource area	Preclosure impacts	Postclosure impacts
Land use and ownership	Small; about 9.1 km^2 (2,200 acres) of disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use. (Section 4.1.1)	Small; potential for limited access into the area; reclamation of disturbed land would restore preconstruction conditions; the only surface features remaining would be markers. (Section 5.0)
Air quality	Small; releases well below regulatory limits (less than 3 percent) for all criteria pollutants except particulate matter. Maximum releases of PM_{10} would be 40 percent of limit at land withdrawal area boundary. (Section 4.1.2.5)	Small; population doses from release of gaseous radionuclides would be on the order of 1×10^{-8} person-rem in the 80-km (50-mile) radius around the repository. (Section 5.6)
Hydrology		
Surface water	Small; land disturbance would result in minor changes to runoff and infiltration rates; minimal potential for contaminants to be released and reach surface water; only ephemeral drainage channels would be affected. Facilities would be constructed above flood zones or diversion channels would be constructed to keep flood waters away; floodplain assessment concluded impacts would be small. (Section 4.1.3.1)	Small; potential sources for surface water contamination would no longer be present. (Section 5.0)
Groundwater	Small to moderate; minimal potential to change recharge rates and for contaminants to be released and reach groundwater; peak water demand (430 acre-feet per year) below the lowest estimate of the groundwater basin's perennial yield (580 acre-feet); after construction, water demand would decrease to 260 acre-feet per year or less. Groundwater would be withdrawn from existing wells and possibly a new well to support Gate 510 facilities. (Section 4.1.3.2)	Estimated releases over the first 10,000 years would result in a mean and median annual individual dose that would not exceed 0.24 millirem and 0.12 millirem, respectively, to an RMEI hypothetically located 18 kilometers (11 miles) from the repository. The analysis of the post-10,000-year period resulted in a mean and median annual individual dose that would not exceed 2.3 millirem and 0.98 millirem, respectively, to the RMEI at the same location. Expected uptakes from nonradioactive hazardous chemicals would all be less than the Oral Reference Doses for any of these substances. (Section 5.5)
Biological resources and soils	Small; loss of up to 9.1 km^2 (2,200 acres) of desert soil, habitat, and vegetation, but no loss of rare or unique habitat or vegetation; adverse impacts to individual threatened desert tortoises and loss of a small amount of low-density tortoise habitat, but no adverse impacts to the species as a whole; reasonable and prudent measures would minimize impacts; no adverse impacts to wetlands. (Section 4.1.4)	Small; slight increase in surface soil temperature directly over repository, lasting from approximately 200 to 10,000 years, could result in a temporary shift in plant and animal communities in the affected area; impacts to individual threatened desert tortoises would decrease as activity level at repository decreased; no temperature-driven change in desert tortoise sex-ratio would be likely; sediment load in ephemeral water courses could temporarily increase coincident with changes to soil and vegetation characteristics. (Section 5.10)

Table 2-2. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Cultural resources	Small; ground disturbances and activities that could destroy or modify the integrity of archaeological or cultural resource sites would be minimized through avoidance of sites and mitigation. Indirect impacts that could result from easier physical access to the land withdrawal area, such as unauthorized excavation and collection of artifacts, would be mitigated by training, monitoring and establishing long-term management of sites. Opposing Native American viewpoint exists. (Section 4.1.5)	Small; potential for limited access into the area; opposing American Indian viewpoint. (Section 5.0)
Socioeconomics		
New jobs (percent of workforce in affected counties)	Construction: Small impacts in region; peaks are 0.05 percent above baseline in Clark County and 1.52 percent above baseline in Nye County. Operations: Small impacts in region; peaks are 0.06 percent above baseline in Clark County and 2.0 percent above baseline in Nye County. (Section 4.1.8)	Small; no workers, no impacts. (Section 5.0)
Peak real disposable income (million dollars)	Construction: Small impacts in region; peaks are $41.7 million (0.05-percent increase) in Clark County and $17.1 million (1.16-percent increase) in Nye County. Operations: Small impacts in region; peaks are $58.3 million (0.05-percent increase) in Clark County and $27.7 million (1.15-percent increase) in Nye County. (Section 4.1.8)	Small; no workers, no impacts. (Section 5.0)
Peak incremental Gross Regional Product (million dollars)	Construction: Small impacts in region; peaks are $58.9 million (0.05-percent increase) in Clark County and $22.7 million (1.42-percent increase) in Nye County. Operations: Small impact in region; peaks are $98.7 million (0.05-percent increase) in Clark County and $68.9 million (2.65-percent increase) in Nye County. (Section 4.1.8)	Small; no workers, no impacts. (Section 5.0)
Occupational and public health and safety		
Public, Radiological		
MEI (probability of an LCF)	0.00029 (Section 4.1.7)	1.4×10^{-7} (Section 5.5)
Population (LCFs)	8 (Section 4.1.7)	Not calculated.

Table 2-2. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Occupational and public health and safety (continued)		
Public, Nonradiological		
Fatalities due to emissions	Small; exposures well below regulatory limits. (Section 4.1.7)	Small; exposures well below regulatory limits. (Section 5.0)
Workers (involved and noninvolved)		
Radiological (LCFs)	4.4 (Section 4.1.7)	No workers; no impacts. (Section 5.0)
Nonradiological fatalities (includes commuting traffic fatalities)	37 (Section 4.1.7)	No workers; no impacts. (Section 5.0)
Accidents, Radiological		
Public MEI (probability of an LCF)	7.2×10^{-11} to 1.4×10^{-5} (Section 4.1.8)	Not applicable.
Public Population (LCFs)	2.6×10^{-7} to 0.16 See Section 4.1.8	Not applicable.
Workers	6.6×10^{-5} to 2.3 rem (4.0×10^{-8} to 1.4×10^{-3} LCF) (Section 4.1.8)	Not applicable.
Noise and vibration	Small; impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels—controls and protection would be used as necessary. (Section 4.1.9)	Small; no activities, therefore, no noise or ground vibration. (Section 5.0)
Aesthetics	Small; the presence of exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several kilometers, especially west of Yucca Mountain. (Section 4.1.10)	Small; the only constructed surface features remaining would be markers. (Section 5.0)
Utilities, energy, materials, and site services	Small; use of materials would be small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would need enhancement. (Section 4.1.11)	Small; no use of materials or energy. (Section 5.0)

Table 2-2. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Waste and hazardous materials	Construction/demolition debris – 476,000 cubic meters (AA cubic yards) Industrial wastewater – 1.2 million cubic meters (BB gallons) Sanitary sewage – 2.0 million cubic meters (CC gallons) Sanitary/industrial waste – 100,000 cubic meters (DD cubic yards) Hazardous waste – 8,900 cubic meters (EE cubic yards) Low-level radioactive waste – 7,400 cubic meters (FF cubic yards) None of the projected volumes of waste would exceed regional capacities for disposal or management. (Section 4.1.12)	Small; no waste generated or hazardous materials used. (Section 5.0)
Environmental justice	No identified high and adverse potential impact to population; no identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. DOE acknowledges the opposing American Indian viewpoint. (Section 4.1.13)	Small; no disproportionately high and adverse impacts to minorities or low-income populations; opposing American Indian viewpoint. (Section 5.0)
Airspace restrictions	Small; if deemed necessary, DOE would obtain exclusive control of a lightly used 48-km^2 (19 square miles) airspace and implement specific restrictions to the Nevada Test Site restricted airspace; airspace restrictions could be lifted once operations were complete. (Section 4.1.15)	Not applicable.
Manufacturing repository components		
Air quality	Small; annual pollutant emissions from component manufacturing would be 0.4 percent or less of the regional emissions for a typical manufacturing location. (Section 4.1.14)	Not applicable.
Occupational and public health and safety	Small; 1,700 reportable occupational injuries and illnesses and 0.61 fatality over entire manufacturing campaign. (Section 4.1.14)	Not applicable.
Socioeconomics	Moderate; the area of a typical manufacturing site could see increases of up to 4.6 percent in the average annual output; up to 2.5 percent in the average annual income; and up to 0.63 percent in the average annual employment. (Section 4.1.14)	Not applicable.

Table 2-2. Potential preclosure and postclosure impacts from repository construction, operation, monitoring, and closure (continued).

Resource area	Preclosure impacts	Postclosure impacts
Materials use	Moderate; annual use of chromium and nickel in component manufacturing would each be roughly 3 percent of U.S. production, or imports in the case of nickel. Annual use of titanium would be 22 percent of U.S. imports in 2006 when there was limited domestic production, but increased domestic production is forecast for the future. (Section 4.1.14)	Not applicable.
Waste generation	Small; a typical manufacturing facility would generate 7.5 metric tons (8.3 tons) of liquid waste and 1 metric ton (1.1 tons) of solid waste per year. (Section 4.1.14)	Not applicable.
Environmental justice	Disproportionately high and adverse impacts to minority or low-income populations would be unlikely from the manufacturing activities. (Section 4.1.14)	Not applicable.

km = kilometer.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.

2.3.2 POTENTIAL IMPACTS OF NATIONAL AND NEVADA TRANSPORTATION

DOE analyzed the impacts from national and Nevada transportation in Chapter 6 of this Repository SEIS and in the Rail Alignment EIS, respectively. Table 2-3 summarizes the range of transportation impacts both nationally and in Nevada under the mostly rail scenario and with the use of dedicated trains.

The impact analysis for national transportation addresses health and safety impacts from the movement of spent nuclear fuel and high-level radioactive waste from the 72 commercial and 4 DOE sites across the nation to the Yucca Mountain site. It includes the impacts of the loading of these materials at the generator sites and their transportation on U.S. railroads and highways.

As Chapter 6 discusses in more detail, shipments of spent nuclear fuel and high-level radioactive waste would represent a very small fraction of the annual traffic levels on the nation's railroads and highways (0.0002 percent for trucks, 0.006 percent for railcars, and about 0.1 percent for trains). The analysis of national transportation led to the following conclusions:

- The environmental impacts from shipments to land use and ownership; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small in comparison to the impacts of other nationwide transportation activities.

- The radiological health impacts to the public and workers for national transportation activities would be small.

- The transportation accident that is reasonably foreseeable and that would have the highest (or maximum) consequences (the maximum reasonably foreseeable accident) would have an estimated frequency of about 8×10^{-6} per year. This accident would involve a long-duration, high-temperature fire that would engulf a cask. If the accident occurred in an urban area, the estimated population radiation dose would be about 16,000 person-rem. In the exposed population, this would result in an estimated 9 latent cancer fatalities. If the accident occurred in a rural area, the estimated population radiation dose would be about 21 person-rem, and the estimated probability of a single latent cancer fatality in the exposed population would be 0.012 (1 chance in 80).

- For sabotage events involving penetration of a spent nuclear fuel rail cask with a high energy density device, DOE estimated that there would be 19 latent cancer fatalities in the exposed population if the sabotage event occurred in an urban area. If the sabotage event took place in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.029 (1 chance in 30).

For rail transportation in Nevada, Table 2-3 summarizes the impacts from both the Caliente and the Mina implementing alternatives to show the differences between impacts of the two alignments. The impacts are from the summary tables in Chapter 2 of the Rail Alignment EIS. Potential impacts under the shared-use option would be generally the same as impacts under the Proposed Action without shared use, unless otherwise noted. The impacts from construction and operation of a railroad in Nevada would be linear in nature and occur over a range from 470 to 540 kilometers (290 to 340 miles). The analysis led to the following conclusions:

Table 2-3. Potential impacts from national and Nevada transportation.

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Corridor length		Total length (all new construction): 528 to 541 km (328 to 336 miles).	Total length: 452 to 502 kilometers (281 to 312 miles).
Land use and ownership	Small (Section 6.3)[b]	Total surface disturbance: 55 to 61 km^2 (14,000 to 15,000 acres); would result in topsoil loss and increased potential for erosion.	Total surface disturbance: 40 to 48 km^2 (9,900 to 12,000 acres) would result in topsoil loss and increased potential for erosion.
		Loss of prime farmland soils: 1.3 to 1.8 km^2 (320 to 440 acres). Less than 0.1 percent of prime farmland soils in Lincoln and Nye counties.	Loss of prime farmland soils: 0.011 to 0.014 km^2 (2.7 to 3.5 acres). Less than 3 percent of the prime farmland soils of the Walker River Paiute Reservation.
		Land use change on public lands for operations right-of-way.	Land use change on public lands and on Walker River Paiute Reservation for operations right-of-way.
		Private parcels the rail line would cross: 14 to 71. Area of affected private land: 0.33 to 0.72 km^2 (82 to 178 acres).	Private parcels the rail line would cross: 1 to 40. Area of affected private land: 0.21 to 0.59 km^2 (52 to 146 acres).
		Active grazing allotments the rail line would cross: 24 to 27. Animal unit months lost: 1,019 to 1,050. (An animal unit month represents enough dry forage for one mature cow for 1 month.)	Active grazing allotments the rail line would cross: 5 to 8. Animal unit months lost: 159 to 246.
		Sections with unpatented mining claims that would be crossed: 32 to 37.	Sections with unpatented mining claims that would be crossed: 23 to 30.
Air quality	Small (Section 6.3)[b]	Rail line construction would result in PM_{10}, $PM_{2.5}$, and NO_x, increases greater than the 2002 county-wide burden for Lincoln and Nye Counties and in NO_x increase greater than the 2002 county-wide burden for Esmeralda County. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded.	Rail line construction would result in CO, VOC, $PM_{2.5}$, PM_{10}, and NO_x increases greater than the 2002 county-wide burden for Esmeralda County; NO_x increase greater than the 2002 county-wide burden for Nye County; and CO, $PM_{2.5}$, PM_{10} and NO_x increases greater than the 2002 county-wide burdens for Mineral County. Rail line construction would not add any criteria air pollutants greater than the 2002 county-wide burden for Churchill and Lyon counties. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded.
		Rail line operations would add less than about 20 percent to the 2002 county-wide burden of all criteria air pollutants for Lincoln County, less than 6 percent for Esmeralda County, and less than 40 percent for Nye County. Rail line operations would not lead to an exceedance of air quality standards. Construction and operation of a proposed quarry in Lincoln County would not result in exceedances of the NAAQS.	Rail line operations would add less than 35 percent to the 2002 county-wide burden of all criteria air pollutants for both Esmeralda and Nye counties and less than about 1 percent to the 2002 county-wide burden of all criteria air pollutants for Churchill and Lyon counties.

Table 2-3. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]: Caliente implementing alternative	Nevada transportation[a]: Mina implementing alternative
Air quality (continued)			Rail line operations would add less than about 2 percent to the 2002 county-wide emissions for SO_2, CO, $PM_{2.5}$, PM_{10} and VOCs and about 80 percent for NO_x emissions for Mineral County. Rail line operations would not lead to an exceedance of air quality standards.
		Construction and operation of a proposed quarry in Nye County could result in exceeding 24-hour PM_{10} limit, but measures required by the Surface Disturbance Permit would greatly reduce PM_{10} emissions making an exceedance of the NAAQS unlikely. Churchill County. Not applicable. Lyon County. Not applicable. Mineral County. Not applicable.	Operation of a quarry in Esmeralda County during construction of the rail line shows no air pollutant would exceed 60 percent of the NAAQS for any averaging period. Operation of a proposed quarry in Mineral County could result in exceeding 24-hour PM_{10} and $PM_{2.5}$ standards, but measures required by the Surface Disturbance Permit would greatly reduce PM_{10} and $PM_{2.5}$ emissions making exceedances of the NAAQS unlikely. Construction of the Staging Yard at Hawthorne in Mineral County could result in exceeding 24-hour PM_{10} and $PM_{2.5}$ standards in the immediate vicinity under some conditions. Lincoln County. Not applicable.
Hydrology			
Surface water	Small (Section 6.3)[b]	Approximately 0.33 km^2 (81 acres) of wetlands could be filled.	Not more than 28 m^2 (300 square feet) of wetlands would be filled.
Groundwater	Small (Section 6.3)[b]	Physical impacts to existing groundwater resource features such as existing wells or springs resulting from railroad construction and operation would be small.	Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operations would be small.
		Groundwater withdrawals during construction in some areas could impact existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts.	Groundwater withdrawals during construction in some areas could affect existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts.

Table 2-3. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Hydrology (continued)		The impact of proposed groundwater withdrawals on groundwater quality would be small to negligible. The proposed withdrawals would not conflict with water quality standards protecting groundwater resources.	The impact of proposed groundwater withdrawals on groundwater quality would be small to negligible. The proposed withdrawals would not conflict with water quality standards for groundwater resources.
Biological resources	Small (Section 6.3)[b]	Short-term impact to 0.12 to 0.24 km^2 (30 to 59 acres) wetland/riparian habitat. Long-term impact to 0.11 to 0.23 km^2 (27 to 57 acres) wetland/riparian habitat. Impacts would vary by alternative segment, be localized, and could include: • Short-term moderate impact on riparian • and wetland vegetation • Long-term moderate impacts on riparian and wetland vegetation • Small to moderate impacts on raptor nesting sites • Short-term moderate impacts to desert big horn sheep	Short-term impact to 0.01 to 0.05 km^2 (2.5 to 12 acres) wetland/riparian habitat. Long-term impact up to 0.01 km^2 (0 to 2.5) wetland/riparian habitat. Impacts would vary by alternative segment, be localized, and could include: • Short-term moderate impact on riparian and wetland vegetation • Short-term moderate impacts to Lahontan cutthroat trout • Small to moderate long-term impacts to Inter-Mountain mixed salt desert scrub and Inter-Mountain Basins Greasewood Flat • Moderate long-term impact to Inter-Mountain mixed salt desert scrub • Short-term and long-term moderate impacts to Western snowy plover • Moderate impact to winterfat communities • Long-term moderate impacts to Inter-Mountain Basins mixed salt desert scrub and Inter-Mountain Basins big sagebrush • Short-term moderate impacts to desert big horn sheep
Cultural resources	Small (Section 6.3)[b]	Numerous archaeological sites identified along segments of alignments subject to sample inventory. Construction could result in impacts to the early Mormon colonization cultural landscape, Pioche-Hiko silver mining community route, 1849 Emigrant Trail campsites, American Indian trail systems, and more than 50 National Register-eligible sites identified along segments of alignments subjected to sample inventory.. Indirect effects to a National Register-eligible rock art site are likely from two quarry sites. No direct impacts to known paleontological resources.	Numerous archaeological sites, including more than 60 National Register-eligible sites, identified along segments of alignments subject to sample inventory. Potential direct and indirect impacts to National Register-eligible sites and to other sites that might be identified during the complete survey. No direct impacts to known paleontological resources.

Table 2-3. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Socioeconomics			
New jobs (percent of workforce in affected counties	Small (Section 6.3)[b]	Construction: Ranges from 0.1-percent increase in Clark County to 5.6-percent increase in Lincoln County. Operation: Ranges from less than 0.1-percent increase in Clark County to 3.9-percent increase in Lincoln County.	Construction: Ranges from 0.02-percent increase in Lyon County to 14-percent increase in Esmeralda County. Operation: Ranges from 0.01-percent increase in Lyon County to 14-percent increase in Esmeralda County.
Peak real disposable income (million dollars)	Small (Section 6.3)[b]	Construction: Ranges from 0.2-percent increase in Clark County to 7.6-percent increase in Esmeralda County. Operation: Ranges from less than 0.1-percent increase in Clark County to 4.7-percent increase in Lincoln County.	Construction: Ranges from 0.03-percent increase in Lyon County to 27-percent increase in Esmeralda County. Operation: Ranges from 0.01-percent increase in Lyon County to 10 -percent increase in Esmeralda County.
Peak incremental Gross Regional Product (million dollars)	Small (Section 6.3)[b]	Construction: Ranges from 0.2-percent increase in Clark County to 28-percent increase in Lincoln County. Operation: Ranges less than 0.1-percent increase in Clark County to 5.2-percent increase in Lincoln County.	Construction: Ranges from 0.04-percent increase in Lyon County to 57-percent increase in Esmeralda County. Operation: Ranges less than 0.01-percent increase in Lyon County to 24-percent increase in Esmeralda County.
Occupational and public health and safety			
Public, Radiological			
MEI (probability of an LCF)	1.3×10^{-4}	4.7×10^{-6}	4.7×10^{-6}
Population (LCFs)	0.63 to 0.69	6.3×10^{-5} to 1.5×10^{-4}	8.2×10^{-4} to 8.6×10^{-4}
Workers (involved and noninvolved)			
MEI (probability of an LCF)[c]	0.015	0.015	0.015
Radiological (LCFs)	9.8 to 10	0.78	0.77 to 0.79
Nonradiological fatalities (includes commuting traffic and vehicle emissions fatalities)	63 to 65	21	22

Table 2-3. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Noise and vibration	Small (Section 6.3)[b]	Noise from construction activities would exceed Federal Transit Administration guidelines in two locations. Noise from rail construction would be temporary. There would be no adverse noise or vibration impacts from construction trains or from operational train activity.	Noise impacts from construction would be considered temporary adverse impacts at two locations. Noise from operations would create adverse noise impacts at two locations. There would be no vibration impacts from construction trains or from operational train activity.
Aesthetics	Small (Section 6.3)[b]	Small to moderate impact along rail alignment (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, staging yard, and quarries.	Small to moderate impact along rail alignment (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, staging yard, and quarries.
Utilities, energy, materials, and site services	Small (Section 6.3)[b]	Utility interfaces: Potential for short-term interruption of service during construction. No permanent or long-term loss of service or prevention of future service area expansions.	Utility interfaces: Potential for short-term interruption of service during construction. No permanent or long-term loss of service or prevention of future service area expansions.
		Public water systems: Most water would be supplied by new wells; small effect on public water systems from population increase attributable to construction and operation employees.	Public water systems: Most water would be supplied by new wells; small effect on public water systems from population increase attributable to construction and operation employees.
		Wastewater systems: Dedicated wastewater treatment systems would be provided at construction camps and operations facilities; small impact on public systems from population increase attributable to construction and operation employees.	Wastewater systems: Dedicated wastewater treatment systems would be provided at construction camps and operations facilities; small impact on public systems from population increase attributable to construction and operation employees.
		Telecommunications: Dedicated telecommunication systems; minimal reliance on communications providers.	Telecommunications: Dedicated telecommunication systems; minimal reliance on communications providers.
		Electricity: Peak demand would be within capacity of regional providers.	Electricity: Peak demand would be within capacity of regional providers.
		Fossil fuels: Fossil-fuel demand would be approximately 6.5 percent of state-wide use during construction and less than 0.25 percent of state-wide use during operation. Demand could be met by existing regional supply systems and suppliers. For the Shared-Use Option, demand would be less than 0.3 percent of state-wide use during operation. Demand could be met by existing regional supply systems and suppliers.	Fossil fuels: Fossil-fuel demand would be approximately 6 percent of state-wide use during construction and less than 0.25 percent of statewide use during operation. Demand could be met by existing regional supply systems and suppliers. For the Shared-Use Option, demand would be less than 0.3 percent of state-wide use during operation. Demand could be met by existing regional supply systems and suppliers.

Table 2-3. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente implementing alternative	Mina implementing alternative
Utilities, energy, materials, and site services (continued)		Materials: Material requirements such as steel, concrete, and ballast would generally be very small in relation to supply capacity.	Materials: Material requirements such as steel, concrete, and ballast would generally be very small in relation to supply capacity.
Hazardous materials and waste	Small (Section 6.3)[b]	Small (Apex Landfill) to moderate (smaller landfills) impacts from nonhazardous waste (solid and industrial and special waste) disposal. Small impacts from use of hazardous materials. Small impacts from hazardous waste disposal. Small impacts from low-level radioactive waste disposal for wastes that would be generated at the Cask Maintenance Facility.	Small (Apex Landfill) to moderate (smaller landfills) impacts from nonhazardous waste (solid and industrial and special waste) disposal. Small impacts from use of hazardous materials. Small impacts from hazardous waste disposal. Small impacts from low-level radioactive waste disposal for wastes that would be generated at the Cask Maintenance Facility.
Environmental justice	Small (Section 6.3)[b]	Constructing and operating the proposed rail line along the Caliente rail alignment would not result in disproportionately high and adverse impacts to minority or low-income populations.	Constructing and operating the proposed rail line along the Mina rail alignment would not result in disproportionately high and adverse impacts to minority or low-income populations.

a. Short-term impacts for the Rail Alignment EIS would occur during the construction phase (4 to 10 years). Long-term impacts would occur throughout and beyond the life of the railroad operations phase (up to 50 years).

b. With the exception of occupational and public health and safety impacts, because shipments of spent nuclear fuel and high-level radioactive waste would comprise only small fractions of total national highway and rail traffic, the environmental impacts of the shipments on land use and ownership; *hydrology*; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small in comparison to the impacts of other nationwide transportation activities

c. Based on a worker who would receive the administrative dose limit of 500 millirem per year (DIRS 156764-DOE 1999, p. 2-3).

CO = Carbon monoxide.
km = kilometer.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NAAQS = National Ambient Air Quality Standards.
NO_x = Nitrous oxides.
SO_2 = Sulfur dioxide.
VOC = Volatile organic compounds.

- Impacts from the transportation of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to Yucca Mountain would be low for either the Caliente or Mina alignment, which would connect to an existing railroad at Caliente or Hawthorne, Nevada, respectively.

- Table 2-3 illustrates that the Mina implementing alternative would be environmentally preferable in comparison to the Caliente implementing alternative. In general, the Mina implementing alternative would have fewer impacts to private land use, less surface disturbance, lower wetlands impacts, and lower air quality impacts than the Caliente implementing alternative. However, the Mina implementing alternative remains the nonpreferred alternative due to the objection of the Walker River Paiute Tribe to the transportation of spent nuclear fuel and high-level radioactive waste through its Reservation.

2.3.3 POTENTIAL IMPACTS OF THE NO-ACTION ALTERNATIVE

Table 2-4 summarizes the potential impacts of the No-Action Alternative from Chapter 7 of this Repository SEIS. Because there would be no construction or operation of a railroad under the No-Action Alternative for the Rail Alignment EIS, there would be no impacts. Therefore, this section does not further discuss the No-Action Alternative for the Rail Alignment EIS.

For the No-Action Alternative for the Proposed Action, short-term actions would include termination of activities and reclamation at the Yucca Mountain site as well as continued management and storage of spent nuclear fuel and high-level radioactive waste at the commercial and DOE sites across the United States. The information in Table 2-4 shows that the short-term (up to 100 years) environmental impacts for the No-Action Alternative would generally be small.

Under No-Action Alternative Scenario 1, DOE would continue to manage spent nuclear fuel and high-level radioactive waste at the DOE sites, and commercial utilities would continue to manage their spent nuclear fuel at their sites, on a long-term basis to isolate the material from human access with institutional control. Under Scenario 2, DOE assumed there would be no effective institutional control after 100 years. The spent nuclear fuel and high-level radioactive waste storage facilities would begin to deteriorate, and radioactive materials could escape to the environment and contaminate the local atmosphere, soils, surface water, and groundwater, thereby representing a considerable human health risk, as Table 2-4 indicates.

The analysis led to the following conclusions:

- For Scenario 2, from 0.04 to 0.4 square kilometer (10 to 100 acres) of land at each generator site could become contaminated to the extent that the land would not be usable for long periods. There would be no such impacts for Scenario 1.

- For Scenario 2, there could be low levels of contamination in the surface watershed and high concentrations of contaminants in the groundwater downstream of the commercial and DOE sites for long periods. There would be no such impacts for Scenario 1.

- For Scenario 2, estimated long-term radiological impacts to the public would be high (1,000 latent cancer fatalities over 10,000 years) in comparison to the first 10,000 years for the Proposed Action.

Table 2-4. Potential impacts from the No-Action Alternative.

		Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	100 years	Scenario 1	Scenario 2
Land use and ownership	DOE would require no new land to support decommissioning and reclamation. Decommissioning and reclamation would include removal or shutdown of existing surface and subsurface facilities and restoration of disturbed lands, including soil stabilization and revegetation of disturbed areas.	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential contamination of 0.04 to 0.4 km^2 (9.8 – 98 acres) around each of the existing commercial and DOE sites.
Air quality	Dismantling and removal of existing structures, recontouring, and revegetation would generate fugitive dust that would be below the regulatory limit.	Small; releases and exposures well below regulatory limits.	Small; releases and exposures well below regulatory limits.	Small; degraded facilities would preclude large atmospheric releases.
Hydrology				
Surface water	Recontouring of terrain to restore the natural drainage and manage potential surface-water contaminant sources would minimize surface-water impacts.	Small; minor changes to runoff and infiltration rates.	Small; runoff during storage and reconstruction would be controlled in stormwater holding ponds; active monitoring would ensure quick response to leaks or releases; commercial and DOE sites for storage likely would be outside of flood zones.	Large; potential for radiological releases and contamination of drainage basins downstream of commercial and DOE sites (concentrations potentially exceeding current regulatory limits).
Groundwater	DOE would use a small amount of groundwater during the decommissioning and reclamation.	Small, use would be small in comparison with other site use.	Small; use would be small in comparison with other site use.	Large; potential for radiological contamination of groundwater around the commercial and DOE sites.
Biological resources and soils	Reclamation would result in the restoration of 1.4 km^2 (346 acres) of habitat. Site reclamation would include soil stabilization and revegetation of disturbed areas. Some animal species could take advantage of abandoned tunnels for shelter. Decommissioning and reclamation could produce adverse impacts to the threatened desert tortoise.	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential adverse impacts at each of the sites from subsurface contamination of 0.04 to 0.4 km^2 (9.8 – 98 acres).

Table 2-4. Potential impacts from the No-Action Alternative (continued).

		Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	100 years	Scenario 1	Scenario 2
Cultural resources	Leaving roads in place after decommissioning could have an adverse impact on cultural resources by increasing public access to the site. Preserving the integrity of important archeological sites and resources important to American Indians could be difficult.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; no construction or operation activities; therefore, no impacts.
Socioeconomics	Loss of approximately 4,700 jobs (1,800-person workforce for decommissioning and reclamation, 1,400-person engineering and technical personnel in locations other than the repository site, and 1,500 indirect jobs) in the socioeconomic region of influence. Nye County collects most of the federal monies associated with the repository project. The No-Action Alternative would result in the loss of payments-in-lieu-of-taxes to Nye County.	Small; population and employment changes would be small compared with totals in the regions.	Small; population and employment changes would be small compared with totals in the regions.	No workers; therefore, no impacts
Occupational and public health and safety				
Public – Radiological MEI (probability of an LCF)		5.2×10^{-6}[(a)]	1.6×10^{-6}[(a)]	(b)
Public – Population (LCFs)	0.001	0.49[a]	3.1[a]	1,000[c]
Public – Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Moderate to large; substantial increases in releases of hazardous substances and exposures to the public.
Workers – Radiological (LCFs)	0.09	24[a]	15[a]	No workers; therefore, no impacts.
Workers – Nonradiological fatalities (includes commuting traffic fatalities)	Less than 0.15	9	1,080	No workers; therefore, no impacts.

Table 2-4. Potential impacts from the No-Action Alternative (continued).

Resource area	Repository	Commercial and DOE sites — Short-term: 100 years	Long-term (100 to 10,000 years): Scenario 1	Long-term (100 to 10,000 years): Scenario 2
Accidents				
Public – Radiological MEI (probability of an LCF)	None	None	None	Not applicable.
Public – Population (LCFs)	None	None.	None.	4 to 16[d]
Workers	Accident impacts would be limited to those from traffic and typical industrial hazards during construction or excavation activities. These were estimated at 94 total recordable cases and 45 lost workday cases.	Large; for some unlikely accident scenarios workers probably would be severely injured or killed; however, DOE or NRC would manage facilities safely during continued storage operations.	Large; for some unlikely accident scenarios workers would probably be severely injured or killed.	No workers; therefore, no impacts
Traffic and transportation	Less than 0.15 traffic fatality would be likely during decommissioning and reclamation.	Small; local traffic only.	Small; local traffic only.	No activities, therefore no traffic.
Noise and vibration	Noise levels would be no greater than the current baseline noise environment at the Yucca Mountain site.	Small; transient and not excessive, less than 85 dBA.	Small; transient and not excessive, less than 85 dBA.	No activities, therefore, no noise.
Aesthetics	Site decommissioning and reclamation would improve the scenic value of the site, which DOE would return as close as possible to its predisturbance state.	Small; storage would continue at existing sites; expansion as needed.	Small; storage would continue at existing sites, with expansion as needed.	Small; aesthetic value would decrease as facilities degraded.
Utilities, energy, materials, and site services	Decommissioning would consume electricity, diesel fuel, and gasoline. The amounts of use would not adversely affect the utility, energy, or material resources of the region.	Small; materials and energy use would be small in comparison to total regional use.	Small; materials and energy use would be small in comparison to total regional use.	No use of materials or energy; therefore, no impacts.
Waste management	Decommissioning would generate some waste that would require disposal in existing Nevada Test Site landfills. DOE would minimize waste by salvaging most equipment and many materials.	Small; waste generated and materials used would be small in comparison to total regional generation and use.	Small; waste generated and materials used would be small in comparison to total regional generation and use.	No generation of waste or use of hazardous materials; therefore, no impacts.

Table 2-4. Potential impacts from the No-Action Alternative (continued).

		Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	100 years	Scenario 1	Scenario 2
Environmental justice	The No-Action Alternative at the repository location would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative during the first 100 years at commercial and DOE sites would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative under Scenario 1 at commercial and DOE sites would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative under Scenario 2 at commercial and DOE sites could potentially result in disproportionately high and adverse impacts to minority or low-income populations.

a. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem; no change to external dose coefficients.
b. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death could be caused by acute direct radiation exposure.
c. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem and ingestion dose coefficients that overall are about 25 percent of the coefficients for the Yucca Mountain FEIS.
d. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem and inhalation dose coefficients that are approximately the same as coefficients for the Yucca Mountain FEIS.

dBA = A-weighted decibels.
DOE = U.S. Department of Energy.
FEIS = Yucca Mountain Final Environmental Impact Statement.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
SEIS = Repository Supplemental Environmental Impact Statement.

- For Scenario 1, estimated long-term (10,000 years) fatalities associated with Scenario 1 would be about 1,100, primarily to the workforce at the storage sites.

- For both scenarios, the risks in relation to sabotage and diversion of fissionable materials at the commercial and DOE sites would be much greater than they would be if the materials were in a deep geologic repository.

2.3.4 SUMMARY OF POTENTIAL PRECLOSURE IMPACTS OF THE PROPOSED ACTION

This section presents the total estimated environmental impacts for the Proposed Action. It combines the environmental impacts from the construction, operation, monitoring, and closure of the repository (Table 2-2) with the environmental impacts from transportation activities (Table 2-3).

As construction of the rail corridor would approach the physical location of the repository and its surface facilities, the potential for impacts to overlap would increase. In most instances, DOE evaluated the potential impacts qualitatively and judged them to be small. However, there are several air quality and groundwater impacts from the repository and the rail actions that DOE could sum and quantify. The following paragraphs discuss those results.

Air Quality. Chapter 4, Section 4.1.2 describes air quality impacts for the repository. Chapter 6, Section 6.4 discusses air quality impacts from rail construction and operation. The air quality impacts from simultaneous construction of the proposed repository and of the railroad and associated rail facilities would not produce criteria pollutant concentrations that exceeded the regulatory limit at the boundary of the analyzed land withdrawal area. Table 2-5 shows the combined estimated concentrations of criteria

Table 2-5. Maximum construction analytical period concentrations of criteria pollutants at the analyzed land withdrawal area boundary from both repository and rail construction activities (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Carbon monoxide	8-hour	10,000	300	3.0
	1-hour	40,000	2,400	5.9
Nitrogen dioxide	Annual	100	2.8	2.8
Sulfur dioxide	Annual	80	0.0022	0.0027
	24-hour	365	0.18	0.048
	3-hour	1,300	0.86	0.066
PM_{10}	24-hour	150	130	84
$PM_{2.5}$	Annual	15	0.16	1.1
	24-hour	35	13	37
Cristobalite	Annual	10[e]	0.048	0.48

a. Appendix B describes the analysis of maximum concentrations and percent of regulatory limits.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.22097 (Table 3-5).
d. Sum of highest estimated concentrations at the accessible land withdrawal boundary regardless of direction. Does not include background concentrations. (Appendix B contains more information.)
e. There are no regulatory limits for public exposure to cristobalite. An EPA health assessment states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 micrograms per cubic meter × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrometers per cubic meter was established as a benchmark for comparison.

pollutants at the land withdrawal boundary. Simultaneous operation of the repository, railroad, and its facilities also would not produce criteria pollutant concentrations that exceeded the regulatory limit at the land withdrawal area boundary. In addition, while DOE would implement dust suppression measures during construction of both the repository and railroad to reduce releases of particulate matter, the Department did not take credit for such measures in the analysis. Therefore, the analysis is conservative. The conservative analyses indicate that even if the background concentrations of the criteria pollutants were added to the estimated maximum concentrations of all construction activities, the resultant concentrations would be below the National Ambient Air Quality Standards.

Groundwater. Groundwater withdrawals would occur for both the repository and rail actions from the same hydrographic area, specifically Area 227A, Jackass Flats. For the analysis, DOE assumed the rail corridor construction in the Jackass Flats area would start at the same time as repository construction.

Therefore, DOE has analyzed water demand from both actions when peak demands would overlap to gauge overall impacts to groundwater resources in the Jackass Flats area.

Figure 2-15 shows combined annual water demands during construction and the first few years of the operations period. It shows water demand during this period because it would be the period of greatest fluctuation and would include the year of peak water demand.

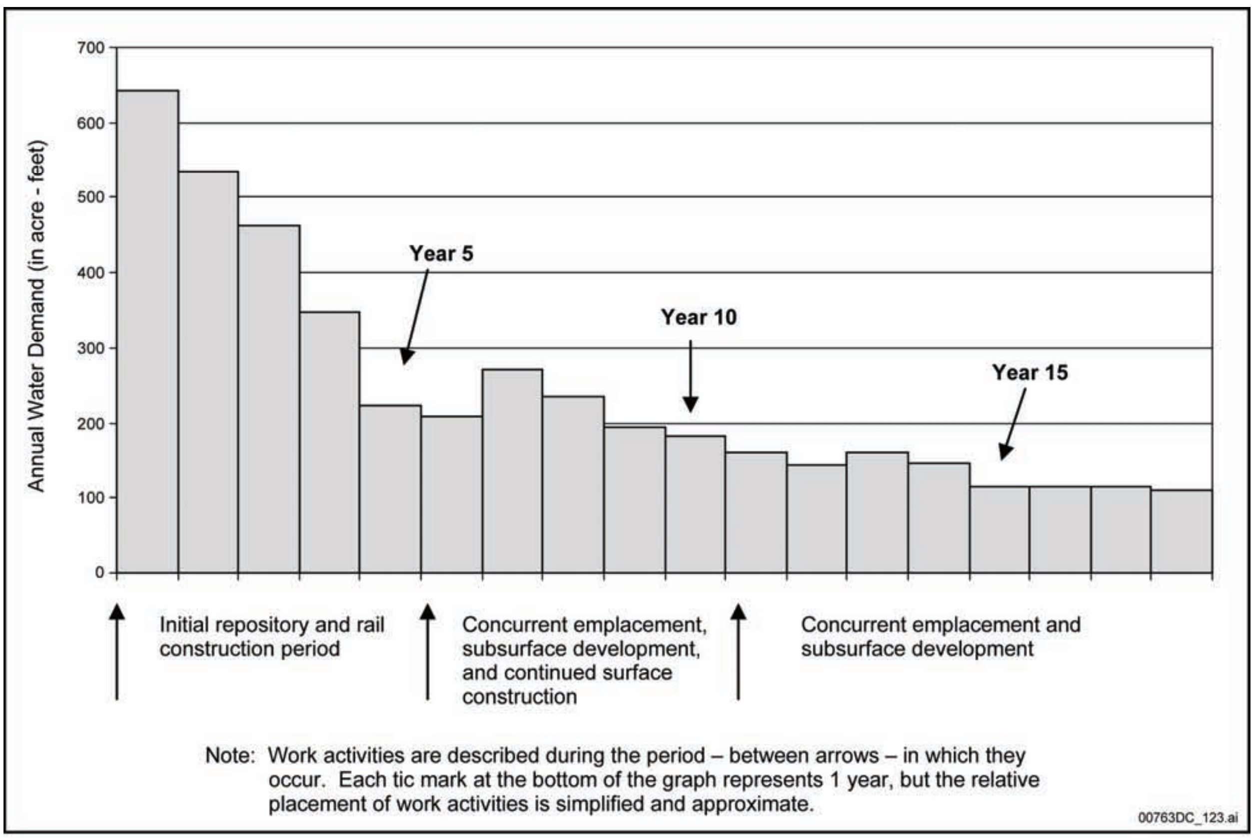


Figure 2-15. Combined annual water demand during the repository and rail construction period and the initial phases of operations.

The highest combined annual water demand for rail and repository activities would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats hydrographic area. For 1 year, the combined demand would be slightly above the lowest estimated value of perennial yield [720,000 cubic meters (580 acre-feet)] for the western two-thirds of this hydrographic area. Coupled with the demand for Nevada Test Site activities in Jackass Flats, the total annual water demand would exceed the lowest estimated value of perennial yield for the western two-thirds of the hydrographic area for 2 years. However, this estimated total combined water demand would still be below estimated values of perennial yield for the entire hydrographic area for all years.

The Proposed Action would withdraw groundwater that would otherwise move into aquifers of the Amargosa Desert, but the combined water demand for the rail, repository, and Nevada Test Site activities in Jackass Flats would have, at most, minor impacts on the availability of groundwater in the Amargosa Desert area in comparison with the quantities of water already being withdrawn there.

Table 2-6 lists the accumulated impacts of the Proposed Action (repository, national transportation, and construction and operation of a railroad in Nevada). It provides ranges of impacts that encompass impacts from both the Caliente and Mina implementing alternatives. In addition, it identifies repository and Nevada transportation impacts that would occur within overlapping regions of influence.

Considering the preclosure and postclosure impacts presented in this Repository SEIS, it can be concluded that the potential impacts associated with the current repository design and operational plans are similar in scale to impacts presented in the Yucca Mountain FEIS.

2.4 Collection of Information and Analyses

As stated in the Yucca Mountain FEIS, some of the studies to obtain or evaluate the information necessary for the assessment of Yucca Mountain as a repository were ongoing and, therefore, some of the information was incomplete. The complexity and variability of any natural system, including that at Yucca Mountain, will result in some uncertainty associated with scientific analyses and findings. It is important to understand that research can produce results or conclusions that might disagree with other research. The interpretation of results and conclusions has led to the development of views that differ from those that DOE has presented.

During the scoping process for this Repository SEIS, DOE received input from a number of organizations interested in the Proposed Action or No-Action Alternative or from potential recipients of impacts from those actions. These organizations included the State of Nevada, local governments, and American Indian tribes. Their input included documents that present research or information that, in some cases, disagrees with the views that DOE presents in this Repository SEIS. The Department reviewed these documents and evaluated their findings for inclusion as part of this Repository SEIS analyses. If the information represented a substantive view, DOE has made every effort to incorporate that view in this Repository SEIS and to identify its source.

Table 2-6. Summary of potential preclosure impacts of the Proposed Action.[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts resulting from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts that occur within overlapping regions of influence
Land use and ownership	Approximately 49 to 70 km^2 (12,000 to 17,000 acres) of total disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use. Loss of prime farmland soils would range from 0.011 to 1.8 km^2, (2.7 to 440 acres) which would be less than 0.1 percent of prime farmland soils in Lincoln and Nye Counties and less than 3 percent of the prime farmland soils of the Walker River Paiute Reservation. Land use change would occur on public lands and on Walker River Paiute Reservation for operations right-of-way. Private parcels the rail line would cross would range from 1 to 71; area of private land affected would range from 0.21 to 0.72 km^2 (52 to 178 acres). Active grazing allotments the rail line would cross would range from 5 to 27. Animal unit months lost would range from 159 to 1,050. Sections with unpatented mining claims that would be crossed would range from 23 to 37.	About 12 km^2 (3,000 acres) of disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use.
Air quality	Releases from construction and operation of the repository would be well below regulatory limits (less than 3 percent) for all criteria pollutants except particulate matter. Maximum releases of PM_{10} would be 40 percent of limit at boundary of land withdrawal area. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded. Rail line operations would not lead to an exceedance of air quality standards. Table 2-3 provides more detail about emissions by county.	Nye County is the only location where Nevada transportation impacts would overlap the repository region of influence. The Nevada transportation emissions would be distributed over the entire county and only the southern portion of the emissions from Nye County would be within the repository region of influence. Modeled concentrations of criteria pollutants at the boundary of the land withdrawal area would not exceed regulatory limits during simultaneous construction of the repository and railroad. Concentrations of all criteria pollutants except for particulate matter would be less than 6 percent of the regulatory limit. Concentrations of $PM_{2.5}$ would not exceed 37 percent, and concentrations of PM_{10} would not exceed 84 percent of the regulatory limit. The simultaneous operation of the repository and railroad would not exceed regulatory limits.

Table 2-6. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts resulting from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts that occur within overlapping regions of influence
Hydrology		
Surface water	Repository land disturbance would result in minor changes to runoff and infiltration rates. At repository site, potential for contaminants to be released and reach surface water would be minimal; only ephemeral drainage channels would be affected, there are no other surface-water resources at the site. Repository facilities would be constructed above flood zones or diversion channels would be constructed to keep flood waters away; floodplain assessment concluded impacts would be small. Up to 0.33 km^2 (81 acres) of wetlands could be filled.	At least two of the drainage channels and floodplains (Busted Butte Wash and Drill Hole Wash) crossed by the railroad would also be affected by construction of repository surface facilities.
Groundwater	Potential for repository actions to change recharge rates and for contaminants to be released and reach groundwater would be minimal. Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operation would be small. Repository peak water demand (430 acre-feet per year) would be below the lowest estimate of perennial yield (580 acre-feet) for the western two-thirds of the groundwater basin; after construction water demand would decrease to 260 acre-feet per year or less. Groundwater withdrawals during rail construction in some areas could affect existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts. Groundwater for repository facility use would be withdrawn from wells in Jackass Flats. Groundwater for rail construction would mostly be withdrawn from new wells.	Water identified for rail line construction includes 572 acre-feet (over four years) plus 6 acre-feet per year for operations, all from the same groundwater basin as for repository activities. A peak annual water demand of 640 acre-feet would result from the combined Nevada transportation and repository needs, assuming construction periods overlapped. This high level would last only 1 year and occur the year repository construction started. The average annual water demand for the combined construction period would be 440 acre-feet. With the exception of the first peak year, all of the combined water demand levels would be below the lowest estimate of perennial yield (580 acre-feet) for the western two-thirds of the groundwater basin. The year of highest water demand would not result in a well drawdown that could affect the nearest public or private wells. Modeling for the Yucca Mountain FEIS showed small to moderate impacts from the Proposed Action groundwater withdrawals that are still applicable. The model's assumed withdrawal rate of 430 acre-feet per year is lower than the peak water demand, but over the life of the project is still conservatively high.

Table 2-6. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Biological resources and soils	Loss of between 49 to 70 km^2 (12,000 to 17,000 acres) of desert soil, habitat, and vegetation. Adverse impacts to desert big horn sheep and special status species including Lahontan cutthroat trout, western snowy plover, and desert tortoise. Short-term impact of up to 0.24 km^2 (59 acres) wetland/riparian habitat. Long-term impact of up to 0.23 km^2 (57 acres) wetland/riparian habitat	Loss of up to 12 km^2 (3,000 acres) of desert soil, habitat, and vegetation, but no loss of rare or unique habitat or vegetation; adverse impacts to individual threatened desert tortoises and loss of a small amount of low-density tortoise habitat, but no adverse impacts to the species as a whole; reasonable and prudent measures would minimize impacts
Cultural resources	Numerous archaeological sites, up to 60 National Register-eligible sites, along segments of alignments subject to sample inventory and 3 sites in the repository region of influence. Opposing Native American viewpoint. Construction could result in impacts to the early Mormon colonization cultural landscape, Pioche-Hiko silver mining community route, 1849 Emigrant Trail campsites, American Indian trail systems. Indirect effects to a National Register-eligible rock art site are likely from two quarry sites. No direct impacts to known paleontological resources.	Small potential for impacts; including three National Register-eligible prehistoric sites; opposing Native American viewpoint.
Socioeconomics		
New jobs (percent of workforce in affected counties	Construction: Peaks range from 0.15 percent above baseline in Clark County to 14-percent increase in Esmeralda County. Operation: Peaks range from 0.01-percent increase in Lyon County to 14-percent increase in Esmeralda County.	Peak increases would be small, less than 1 percent in the region, Clark County, and Nye County when construction of repository and rail overlap.
Peak real disposable income (million dollars)	Construction: Peak percent increases are: • Nye: 1.16 (repository); 0.4 to 0.9 (rail) • Clark: 0.05 (repository); 0.1 (rail) • Lincoln: 4.1 (rail) • Esmeralda: 7.6 to 27 (rail) • Lyon: 0.03 (rail) • Walker River/Paiute Reservation: up to $386,000 • Mineral: 4.5 (rail) • Washoe County/Carson City: less than 0.3 (rail)	For Repository: In Clark County (2034), 58.3 million; in Nye County (2035) $27.5 million For Rail: In Clark County (2011) $100.6 million; in Nye County (2012) $9.6 million.

Table 2-6. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Socioeconomics (continued)		
	Operations: Peak percent increases are: • Nye: 1.15 (repository); 0.1 to 0.3 (rail) • Clark: 0.05 (repository); less than 0.1 (rail) • Lincoln: 4.7 (rail) • Esmeralda: 2.9 to 10 (rail) • Lyon: 0.01 (rail) • Walker River/Paiute Reservation: included in Mineral County • Mineral: 2.8 (rail) • Washoe County/Carson City: less than 0.1 (rail)	
Peak incremental Gross Regional Product (million dollars)	Construction: Peak percent increases are: • Nye: 1.42 (repository); 1.0 to 3.5 (rail) • Clark: 0.05 (repository); less than 0.1 to 0.1 (rail) • Lincoln: 28 (rail) • Esmeralda: 9.5 to 57 (rail) • Lyon: 0.04 (rail) • Walker River/Paiute Reservation: up to $1.4 million • Mineral: 14 (rail) • Washoe County/Carson City: less than 0.3 (rail) Operations: Peak percent increases are: • Nye: 2.65 (repository); 0.2 to 0.5 (rail) • Clark: 0.05 (repository); less than 0.1 (rail) • Lincoln: 5.2 (rail) • Esmeralda: 3.8 to 24 (rail) • Lyon: 0.01 (rail) • Walker River/Paiute Reservation: included in Mineral County • Mineral: 1.9 (rail) • Washoe County/Carson City: less than 0.1 (rail)	For Repository: In Clark County (2034), $98.7 million; in Nye County (2034) $68.9 million. For Rail: In Clark County (2012), $154.5 million; in Nye County (2012), $42.8 million

Table 2-6. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Occupational and public health and safety		
Public, Radiological		
MEI (probability of an LCF)	2.9×10^{-4} (repository) 1.3×10^{-4} (transportation)	See Summary of all preclosure impacts column.
Population (LCFs)	8.6–8.7 (total)	See Summary of all preclosure impacts column.
Public, Nonradiological		
Fatalities due to emissions	Small; exposures well below regulatory limits.	Small; exposures well below regulatory limits.
Workers (involved and noninvolved)		
Radiological (LCFs)	14	See Summary of all preclosure impacts column.
Nonradiological fatalities (includes commuting traffic and vehicle emissions fatalities)	64 to 66 (total)	See Summary of all preclosure impacts column.
Accidents		
Public, Radiological		
MEI (probability of an LCF)	7.2×10^{-11} to 1.4×10^{-5}	See Summary of all preclosure impacts column.
Population (LCFs)	2.6×10^{-7} to 0.16	See Summary of all preclosure impacts column..
Workers, Radiological	6.6×10^{-5} to 2.3 rem (4.0×10^{-8} to 1.4×10^{-3} LCF)	See Summary of all preclosure impacts column.
Noise and vibration	Impacts to public would be low due to large distances from the repository to residences; workers exposed to elevated noise levels – controls and protection used as necessary. Noise from rail construction activities would exceed Federal Transit Administration guidelines in two locations. Noise from rail construction would be temporary. There would be no adverse vibration impacts from construction or operations.	Impacts to public would be low due to large distances from the repository to residences; workers exposed to elevated noise levels – controls and protection used as necessary.
Aesthetics	The exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several miles, especially west of Yucca Mountain. Aesthetic impacts would range from small to moderate along rail alignments (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, staging yard, and quarries.	The exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several miles, especially west of Yucca Mountain.

Table 2-6. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Utilities, energy, materials, and site services	Use of materials would be small in comparison to regional use; some effect on public water systems and public wastewater treatment facilities due to population growth from construction and operations employment; annual fossil-fuel use would be less than 7 percent of state-wide use during construction and less than 2 percent of state-wide use during operation; electric power delivery system to the Yucca Mountain site would have to be enhanced.	Use of materials would be small in comparison to regional use; some effect on public water systems and public wastewater treatment facilities due to population growth from construction and operations employment; annual fossil-fuel use would be less than 7 percent of state-wide use during construction and less than 2 percent of state-wide use during operation; electric power delivery system to the Yucca Mountain site would have to be enhanced.
Waste and hazardous materials	Small impacts from nonhazardous waste (solid and industrial waste) disposal to regional solid waste facilities. Small impacts from use of hazardous materials. Small impacts from hazardous-waste disposal to regional licensed hazardous waste facilities. Small impacts from low-level radioactive waste disposal to a DOE low-level waste disposal site, or Agreement State site, or an NRC-licensed site.	Small impacts from nonhazardous waste (solid and industrial waste) disposal to regional solid waste facilities. Small impacts from use of hazardous materials. Small impacts from hazardous-waste disposal to regional licensed hazardous waste facilities. Small impacts from low-level radioactive waste disposal to a DOE low-level waste disposal site, or Agreement State site, or an NRC-licensed site.
Environmental justice	No identified high and adverse potential impact to population; no identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. (Section 4.1.13) DOE acknowledges the opposing American Indian viewpoint.	Constructing and operating the proposed geologic repository at Yucca Mountain and constructing and operating the railroad to transport spend nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository would not result in disproportionately high and adverse impacts to minority or low-income populations.
Manufacturing repository components	Small impacts to all resources with the exception of moderate socioeconomic and materials impacts.	Not applicable.
Airspace restrictions	Small impact to airspace use; airspace restriction could be lifted once operations have been completed.	Small impacts to airspace use; airspace restriction could be lifted once operations have been completed.

a. Short-term impacts for the Rail Alignment EIS are impacts limited to the construction phase (4 to 10 years). Long-term impacts for the Rail Alignment EIS are impacts that could occur throughout and beyond the life of the railroad operations phase (up to 50 years).

DOE = U.S. Department of Energy.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.

2.4.1 INCOMPLETE OR UNAVAILABLE INFORMATION

DOE and others have continued to gather information since the publication of the Yucca Mountain FEIS. As a result, this Repository SEIS includes information that was not available for the Yucca Mountain FEIS. DOE continues activities for the Performance Confirmation Program; therefore, the generation of information is continuing. However, DOE believes that sufficient information is currently available to assess the range of impacts that could result from the Proposed Action in this Repository SEIS.

2.4.2 UNCERTAINTY

DOE has continued to conduct analyses, one purpose of which is to better define or reduce uncertainties associated with postclosure performance and to reduce health and safety *risks* during operation of the repository. The conclusions of analyses continue to have some associated uncertainty as a result of the assumptions used and the complexity and variability of the process being analyzed. Chapter 5 of this Repository SEIS provides a further description of uncertainties associated with postclosure impacts.

2.4.3 OPPOSING VIEWS

As was the case in the Yucca Mountain FEIS, opposing views are defined in this Repository SEIS as differing views or opinions currently held by organizations or individuals outside DOE. These views are considered to be opposing if they include or rely on data or methods that DOE is not currently using in its own impact analyses.

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

- Have arisen since the Yucca Mountain FEIS was published,
- Address issues analyzed in this Repository SEIS,
- Differ from the DOE position,
- Are based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in this Repository SEIS, or
- Have significant basic differences in the data or methods used in the analysis or to the impacts described in this Repository SEIS.

DOE has included opposing views that meet the above criteria in this Repository SEIS where it discusses the particular topic.

2.4.4 PERCEIVED RISK AND STIGMA

In the Yucca Mountain FEIS, DOE evaluated perceived risk and stigma associated with construction and operation of a repository at Yucca Mountain and from the transportation of spent nuclear fuel and high-level radioactive waste. In the Yucca Mountain FEIS, DOE recognized that nuclear facilities can be perceived to be either positive or negative, depending on the underlying value systems of the individual forming the perception. Thus, perception-based impacts would not necessarily depend on the actual physical impacts or risk of repository operations, including transportation. A further complication is that people do not consistently act in accordance with negative perceptions, and thus the connection between public perception of risk and future behavior would be uncertain or speculative at best.

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

DOE concluded that, although public perception regarding the proposed geologic repository and transportation of spent nuclear fuel and high-level radioactive waste could be measured, there is no valid method to translate these perceptions into quantifiable economic impacts. Researchers in the social sciences have not found a way to reliably forecast linkages between perceptions or attitudes reported in surveys and actual future behavior. At best, only a *qualitative* assessment is possible about what broad outcomes seem most likely. The Yucca Mountain FEIS did identify some studies that report, at least temporarily, a small relative decline in residential property values might result from the designation of transportation corridors in urban areas.

The Yucca Mountain FEIS presented the following conclusions regarding perceived risk and stigma:

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

The more detailed discussion of perceived risk and stigma related to the Proposed Action is incorporated into this Repository SEIS by reference to Chapter 2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp 2-95 to 2-96).

An independent economic impact study (DIRS 172307-Riddel et al. 2003, all) conducted since the publication of the Yucca Mountain FEIS examined, among other things, the social costs of perceived risk to Nevada households living near transportation routes. The study developed such an estimate in terms of households having a willingness to accept compensation for different levels of perceived risk and a willingness to pay to avoid risk. The results of the study indicated that during the first year of transport, net job losses (and associated drop in residential real estate demand and decreases in gross state product) relative to the baseline would occur in response to people moving to protect themselves from transport risk. However, the initial impact would be offset rapidly, as the population shifted to a more risk-tolerant base. The results of this study are similar to those studies identified in the Yucca Mountain FEIS.

Other conclusions of this study are that the public and DOE have widely divergent risk beliefs and that the public is very uncertain about the risks they face. At the same time, over 40 percent of the respondents in a public survey conducted as part of this study felt that DOE information is reliable or very reliable, while another 40 percent feel that DOE's information is somewhat reliable. These results suggest social costs could be mitigated by reducing the risk people perceive from transport through information and education programs that are well researched and effectively presented.

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

2.5 Preferred Alternative

DOE's preferred alternative—to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain—has not changed since the Department published the Yucca Mountain FEIS. The preferred alternative includes using mostly rail as the mode of transportation for spent nuclear fuel and high-level radioactive waste, both nationally and in the State of Nevada. The preferred alternative also includes construction and operation of the proposed railroad along the Caliente rail alignment in the State of Nevada, and to implement the shared-use option as set forth in the Rail Alignment EIS. The analyses in this Repository SEIS, which include those from the Rail Alignment EIS, have not identified any new potential environmental impacts that would be the basis for not proceeding with the Proposed Action.

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172307	Riddel et al. 2003	Riddel, M.; Boyett, M.; and Schwer, R.K. 2003. *Economic Impact of the Yucca Mountain Nuclear Waste Repository on the Economy of Nevada*. Las Vegas, Nevada: University of Nevada, Las Vegas, Center for Business and Economic Research. ACC: MOL.20041207.0449.

3

Affected Environment

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3. AFFECTED ENVIRONMENT

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

Where noted in this chapter of the *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County*, *Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS), DOE summarizes, incorporates by reference, and updates Chapter 3 of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, pp. 3-1 to 3-227) (Yucca Mountain FEIS) and presents new information, as applicable, from studies and investigations that continued after the completion of the Yucca Mountain FEIS. If the Department did not use information from the FEIS, but rather based the information in a subsection on input from continuing studies and investigations, the introduction to that subsection so states and does not reference the FEIS. To ensure that the source of the information is clear, DOE states it is summarizing, incorporating by reference, and updating the FEIS in the introduction to each applicable section or subsection of Section 3.1.

3.1 Affected Environment at the Yucca Mountain Repository Site

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

- Land use and ownership. Land-use practices and land-ownership information in the Yucca Mountain region, which includes overflight restrictions in the Yucca Mountain region (Section 3.1.1);
- *Air quality* and climate. The quality of the air in the Yucca Mountain region and the area's climatic conditions (such as temperature and precipitation) (Section 3.1.2);
- Geology. The *geologic* characteristics of the Yucca Mountain region at and below the ground surface, the frequency and severity of *seismic* activity, volcanism, and mineral and energy resources (Section 3.1.3);

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

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

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

- Socioeconomics. The labor market, population, housing, some public services, real disposable income, Gross Regional Product, government spending, and DOE payment equal to taxes in the Yucca Mountain region (Section 3.1.7);

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

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

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

- Utilities, energy, and site services. The amounts of power supplied to the region, the means by which power is supplied, the availability of gasoline, diesel, natural gas and propane, and the availability of construction materials (Section 3.1.11);

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

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

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

The vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site-selection

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

Resource/Subject Area	Region of Influence
Land use and ownership	The analyzed land withdrawal area, which consists of lands around the proposed repository that DOE would disturb and lands over which DOE would have to obtain permanent control to operate the repository, and lands DOE proposes for an access road from U.S. Highway 95 and where DOE could construct offsite facilities (Section 3.1.1).
Air quality and climate	An approximate 80-kilometer radius around the repository and at the boundary of the land withdrawal area (Section 3.1.2).
	The physiographic setting (characteristic landforms), stratigraphy (rock strata), and geologic structure (structural features that result from rock deformations) of the region and of Yucca Mountain (Section 3.1.3).
Hydrology	Surface water: Construction areas that would be susceptible to erosion, areas that permanent changes in flow would affect, and areas downstream of the repository that eroded soil or potential spills of contaminants would affect. Groundwater: Aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and areas downstream of the repository that repository use or postclosure performance of the repository could affect (Section 3.1.4).
Biological resources and soils	Area that contains all potential surface disturbances that would result from the Proposed Action plus additional area to evaluate local animal populations, roughly equivalent to the analyzed land withdrawal area, as well as land proposed for an access road from U.S. Highway 95 and land where DOE could construct offsite facilities (Section 3.1.5).
Cultural resources	Area that contains all potential surface disturbances that would result from the Proposed Action, as well as land proposed for an access road from U.S. Highway 95 and land where DOE could construct offsite facilities (Section 3.1.6).
Socioeconomics	The two-county (Clark and Nye) area in which repository activities could most influence local economies and populations (Section 3.1.7).
Occupational and public health and safety	Workers at the repository and potentially affected workers at nearby Nevada Test Site facilities and members of the public who reside within an 80-kilometer (50-mile) radius of the geologic repository operations area (Section 3.1.8).
Noise and vibration	The Yucca Mountain site and existing and future residences to the south in the Town of Amargosa Valley (Section 3.1.9).
Aesthetics	The approximate boundary of the analyzed land withdrawal area, an area west of the boundary from where people could see the ventilation stacks, and the area south of the boundary where DOE would construct the access road from U.S. Highway 95 and several buildings (Section 3.1.10).
Utilities, energy, and site services	Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities and cement suppliers) (Section 3.1.11).
Waste and hazardous materials	On- and offsite areas, which would include landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12).
Environmental justice	Varies with resource area and corresponds to the region of influence for each resource area (Section 3.1.13).

Note: Conversion factors are on the inside back cover of this Repository SEIS.
DOE = U.S. Department of Energy.

process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain. Yucca Mountain site characterization activities began in 1989 and continued through 2001. These activities included surface and *subsurface* excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. As of 2001, these activities had disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain. Since 2001, there has been minimal additional land disturbance. Reclamation activities have started and will continue to occur as DOE releases areas from further study.

The existing environment at Yucca Mountain includes the *Exploratory Studies Facility* [which includes the tunnel (*drift)*], the North and South portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, *boreholes*, trenches, roads, and supporting facilities and disturbances from site characterization activities.

3.1.1 LAND USE AND OWNERSHIP

The region of influence for land use and ownership includes the analyzed land withdrawal area, land proposed for an access road from U.S. Highway 95, and land where DOE would construct offsite facilities. The analysis for this Repository SEIS assumed DOE would build the proposed offsite facilities on Bureau of Land Management land near Gate 510 of the Nevada Test Site. This section summarizes, incorporates by reference, and updates Section 3.1.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-6 to 3-12). The following sections summarize important characteristics of land use and ownership. Section 3.1.1.1 discusses regional land use and ownership. Section 3.1.1.2 discusses current land use and ownership at Yucca Mountain. Section 3.1.1.3 discusses the American Indian treaty issue. Section 3.1.1.4 discusses current airspace use near the Yucca Mountain site.

3.1.1.1 Regional Land Use and Ownership

This section summarizes, incorporates by reference, and updates Section 3.1.1.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-6 and 3-7). The Federal Government manages more than 85 percent of the land, about 240,000 square kilometers (93,000 square miles), in Nevada. About 42,000 square kilometers (16,000 square miles) are under state, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are American Indian lands. The Yucca Mountain site is in Nye County, which has an area of approximately 47,000 square kilometers (18,000 square miles) and is the largest county in Nevada. The Federal Government manages almost 93 percent of the land in the county, which includes the Nevada Test and Training Range (formerly Nellis Air Force Range), the Nevada Test Site, Bureau of Land Management-administered lands, a portion of Death Valley National Park, and portions of the Humboldt-Toiyabe National Forest. Private land uses in Nye County include residences, commercial facilities, and industrial sites that are largely, but not exclusively, within the boundaries of unincorporated towns, and agricultural and mining properties inside and outside these towns. The closest year-round housing to the repository is at what was once referred to as Lathrop Wells, about 22 kilometers (14 miles) south of the site; this location is now part of the unincorporated town of Amargosa Valley.

The Bureau of Land Management controls most of the lands to the south of the analyzed land withdrawal area and manages them in accordance to the *Record of Decision for the Approved Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 176043-BLM 1998, all). This resource management plan designates approximately 23.3 square kilometers (9 square miles) of land in the town of Amargosa Valley adjacent to the repository site entrance for disposal to the private sector, which indicates that the land has limited public use. Some land in the vicinity of the intersection of U.S. Highway 95 and Nevada State Route 373 is privately owned.

In 1999, Congress directed the Bureau of Land Management to expedite the conveyance of disposal lands in the vicinity of the intersection of U.S. Highway 95 and State Route 373 for conveyance to Nye County (Public Law 106-113). On March 9, 2001, the Bureau of Land Management issued a notice of realty action (66 FR 14194) to announce the noncompetitive sale of public lands (N-66239) and a recreation and public purpose conveyance in Nye County, Nevada (N-54086), which are both near this intersection (DIRS 181688-Bowlby 2007, all). The Bureau offered realty action N-66239 as a noncompetitive sale of approximately 1.4 square kilometers (350 acres) of public land to Nye County. Under the conditions of sale, Nye County had the exclusive right to purchase any and all of the proposed land at fair market value for a commercial purpose for a period of 5 years. Nye County purchased approximately 0.25 square kilometer (61 acres). The exclusive right to purchase expired on November 28, 2004. Although the exclusive right to purchase under special legislation has expired, Nye County has requested to purchase an additional 1.2 square kilometers (296 acres) by direct sale. In response, the Bureau of Land Management is currently conducting the land appraisal. Once the appraisal is complete, the Bureau will issue a *Federal Register* notice to notify the public of the potential sale and opportunity for comment. The process is likely to take a minimum of 6 months before Nye County may obtain possession of these 1.2 square kilometers, if BLM approves a sale. Realty action N-54086 is a conveyance of 1.9 square kilometers (470 acres) of public land to Nye County for recreational or public purposes. The published intent of Nye County, once the land action is complete, is to lease the land to the Nevada Science and Technology Center, a nonprofit corporation, for the development of the Nevada Space Museum, outdoor exhibit areas, and associated facilities. The Bureau of Land Management sent Nye County a letter in early 2006 to notify the county of the Bureau's intent to close case files such as these that have had a pending land action status for a significant amount of time. In addition, the letter requested action by Nye County if it intended to pursue this conveyance. Nye County and the Bureau of Land Management are involved in ongoing planning efforts for this area.

3.1.1.2 Current Land Use and Ownership at Yucca Mountain

This section summarizes, incorporates by reference, and updates Section 3.1.1.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 3-9). *The Yucca Mountain Development Act of 2002* (Public Law 107-200; 116 Stat. 735) designated the Yucca Mountain site for development as a *geologic repository*. For this Repository SEIS, the Yucca Mountain site is synonymous with the analyzed land withdrawal area. Figure 3-1 shows land use and ownership in the region of influence, including land use agreements and the analyzed land withdrawal area. The analyzed land withdrawal area includes approximately 600 square kilometers (150,000 acres) of land and comprises approximately 320 square kilometers (79,000 acres) administered by DOE (Nevada Test Site), approximately 96 square kilometers (24,000 acres) administered by the U.S. Air Force (Nevada Test and Training Range), approximately 180 square kilometers (44,000 acres) administered by the Bureau of Land Management, and approximately 0.81 square kilometer (200 acres) of private land (Patented Mining Claim No. 27-83-0002). Patented Mining Claim No. 27-83-0002 is an active mining operation for Cind-R-Lite to mine volcanic cinders for use as a sole-source raw material in the manufacture of cinderblocks.

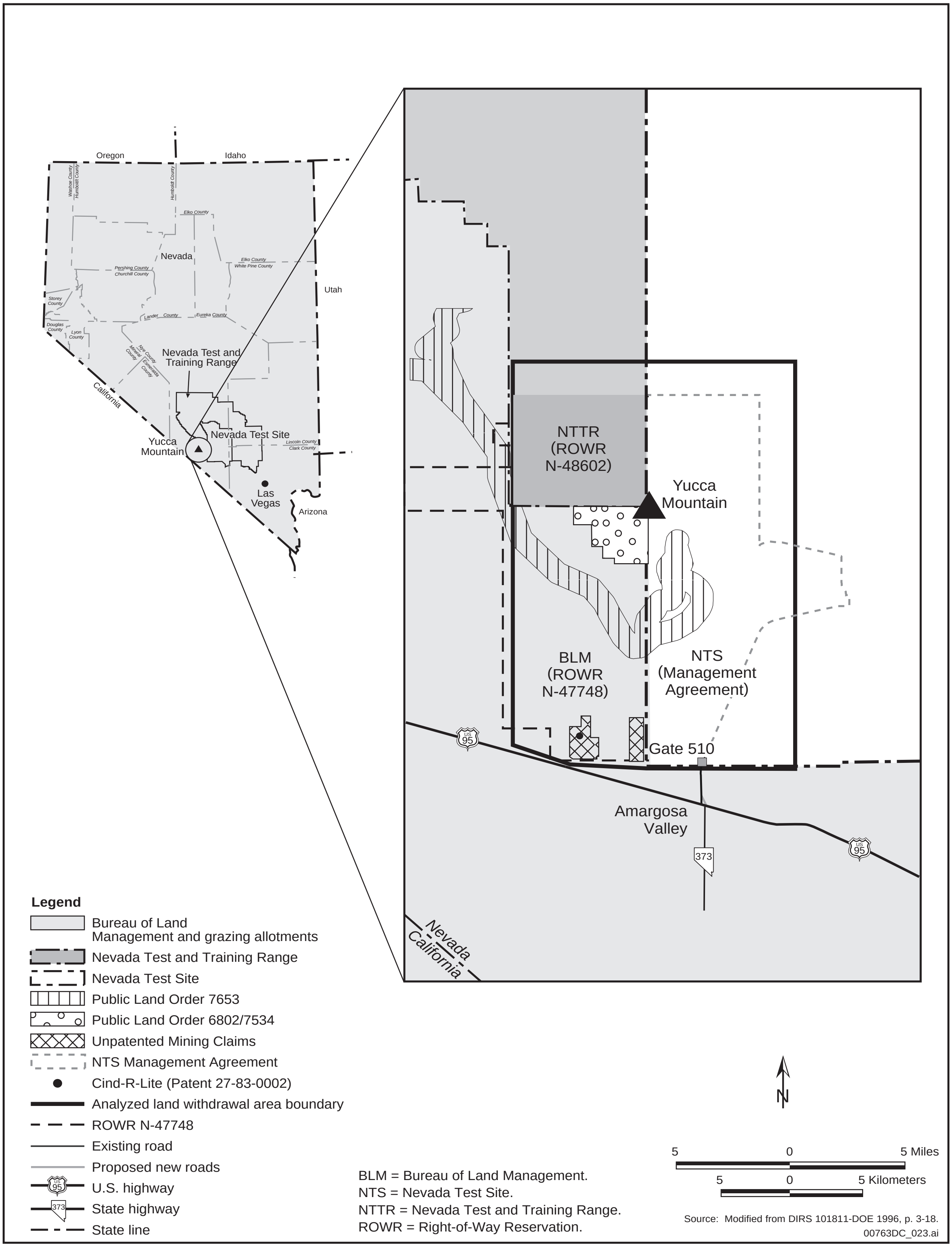


Figure 3-1. Land use and ownership in the region of influence.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the Bureau's current right-of-way reservation (N-47748) for previous Yucca Mountain site characterization activities. This land is open to public use with the exception of approximately 17.4 square kilometers (4,300 acres) near the site of the proposed repository [Public Land Order 6802, extended via Public Land Order 7534 until January 31, 2010 (67 FR 53359)] and the existing patented mining claim.

The Bureau of Land Management manages surface resources on the Nevada Test and Training Range and granted DOE a right-of-way reservation N-48602 in 1994 to use about 75 square kilometers (19,000 acres) of land for site characterization activities. On April 4, 2004, the Bureau renewed the right-of-way reservation, which is effective from April 10, 2004, through January 6, 2008. This right-of-way is currently in the renewal process with the Bureau of Land Management. This land is closed to public access and use.

The Bureau of Land Management issued Public Land Order 7653 in the Federal Register on December 28, 2005 (70 FR 76854). The order withdrew approximately 1,250 square kilometers (310,000 acres) of public land in Nevada in the Caliente *rail corridor* from surface entry and new mining claims for 10 years to enable DOE to evaluate the land for the potential *construction*, *operation*, and maintenance of a *rail line* for the transportation of spent nuclear fuel and high-level radioactive waste. Approximately 49 square kilometers (12,000 acres) of these lands are inside the analyzed land withdrawal area [approximately 26.3 square kilometers (6,500 acres) on Bureau of Land Management land and approximately 23 square kilometers (5,700 acres) on Nevada Test Site land] (Figure 3-1).

The Bureau of Land Management announced the receipt of a land withdrawal application on January 10, 2007, from DOE that requested the withdrawal of approximately 850 square kilometers (210,000 acres) of public land in Nevada from surface entry and mining through December 27, 2015, to evaluate the land for the potential construction, operation, and maintenance of a rail line for the transportation of spent nuclear fuel and high-level radioactive waste (72 FR 1235). The notice segregated the land from surface entry and mining for as long as 2 years (until January 9, 2009) while DOE conducts studies and analyses to support a final decision on the withdrawal application. Approximately 6.3 square kilometers (1,600 acres) of these lands are inside the analyzed land withdrawal area for the repository. Of the 6.3 square kilometers, approximately 1.4 square kilometers (350 acres) are small areas immediately adjacent to the Bureau of Land Management lands withdrawn by Public Land Order 7653. The additional 4.9 square kilometers (1,200 acres) are small areas immediately adjacent to the Nevada Test Site lands withdrawn by Public Land Order 7653 and an area that extends that withdrawal to the north by approximately 1.6 kilometers (1 mile).

The Bureau of Land Management land open to public use contains a number of unpatented mining claims. The Bureau permits off-road vehicle use and there is a designated utility corridor in the southern portion of these lands. A portion of an unused grazing allotment overlaps the analyzed land withdrawal area. This nonactive allotment has no permittees. More detailed information for the land controlled by the Bureau of Land Management in the region of Yucca Mountain is available in the *Record of Decision for the Approved Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 176043-BLM 1998, all).

In addition to disturbances from repository site characterization and confirmation activities, the Nevada Test Site and the U.S. Department of Defense have actively used the land proposed for the repository. To analyze the amount of previously undisturbed land that construction and operation and *monitoring* of the repository would disturb, DOE considers that 2.43 square kilometers (600 acres) were previously disturbed.

3.1.1.3 American Indian Treaty Issue

This section summarizes, incorporates by reference, and updates Section 3.1.1.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-11 and 3-12). The Western Shoshone Tribe maintains that the Ruby Valley Treaty of 1863 gives them rights to 97,000 square kilometers (37,000 square miles) in Nevada, which includes the Yucca Mountain region. A legal dispute with the Federal Government led to a monetary award as payment for the land. However, the Western Shoshone have not accepted this award and maintain that there is no settlement. The U.S. Treasury is holding the monies in an interest-bearing account. In 1985, the U.S. Supreme Court decided that the United States has met its obligations and, as a consequence, the aboriginal title to the land has been extinguished (United States v. Dann, 470 U.S. 39, 1985).

In July 2004, President George W. Bush and Congress approved payment to the Western Shoshone Tribe of more than $145 million in compensation and accrued interest based on the 1872 value of 97,000 square kilometers (37,000 square miles) (Public Law 108-270; 118 Stat. 805). Under provisions of the law, payment by the United States Government officially subsumed Western Shoshone claims to 97,000 square kilometers of land in Nevada, Utah, California, and Idaho, based on the Ruby Valley Treaty of 1863. The law will distribute approximately $145 million in funds that the Indian Land Claims Commission awarded the Tribe. There are approximately 6,000 eligible tribal members, and the law sets aside a separate revenue stream for educational purposes.

On March 4, 2005, the Western Shoshone National Council filed a lawsuit against the United States, DOE, and the U.S. Department of the Interior in the federal district court in Las Vegas, Nevada. The complaint sought an injunction to stop federal plans for the use of Yucca Mountain as a repository based on the five established uses of the land within the boundaries of the 1863 Ruby Valley Treaty. On May 17, 2005, the U.S. District Court rejected a request from the Western Shoshone National Council for a preliminary injunction to stop DOE from applying for a license for the Yucca Mountain Project.

In 2006, a contingent of Western Shoshones sued Union Pacific Railroad, BNSF Railroad Company, Newmont Gold Company, Barrick Goldstrike Mines Inc., Glamis Gold Inc., Nevada Land Resource Company, Sierra Pacific Power Company, and Idaho Power Company in federal court in Reno, Nevada. The lawsuit claims that the companies violated the Ruby Valley Treaty by possessing land transferred from the U.S. Government.

3.1.1.4 Airspace Use near Yucca Mountain

There are three types of airspace in the proximity of Yucca Mountain: Class A, Class G, and special use. Class G airspace is that airspace from the ground level to 18,000 feet above mean sea level; Class G airspace is uncontrolled airspace, over which air traffic control does not exercise authority. Class A airspace is airspace above 18,000 feet above mean sea level. Special-use airspace is airspace "wherein activities must be confined because of their nature, or wherein limitations are imposed upon aircraft operations that are not a part of those activities, or both" (DIRS 182869-FAA 2007). Special-use airspace is further subdivided into restricted areas and military operations areas, as well as four other categories that are not discussed in this Repository SEIS. The Federal Aviation Administration defines the two types of special-use airspace that occur in the proximity of Yucca Mountain as follows:

- Restricted areas are a type of special-use airspace that separate or confine air activities that are considered dangerous or unsafe to aircraft not involved in the activity. Regulations prohibit flights by nonparticipating military and civil or commercial aircraft in this airspace without the controlling authority authorization. Restricted airspace can be designated for joint use, in which air traffic controllers can route nonparticipating civil or military aircraft when there is no conflict with scheduled activities. If the area is not designated for joint use, nonparticipating aircraft are normally not permitted at any time. Restricted areas are rulemaking actions that are implemented by a formal amendment to 14 CFR Part 73.

- Military operations areas are a type of special-use airspace that allow for the separation of military training activities from other air traffic. Military operations areas are nonrulemaking actions.

Figure 3-2 shows the types of airspace in the vicinity of Yucca Mountain. The figure shows the proximity of the special-use airspace, including restricted areas and military operations areas, to Yucca Mountain and the proposed land withdrawal area. The Yucca Mountain site is several kilometers from restricted areas R-4806, R-4807, and R-4809, which occupy approximately 12,100 square kilometers (4,700 square miles). These restricted areas, which are part of the Nevada Test and Training Range, are used extensively by the U.S. Air Force for training and test flights. The Air Force provides operational control for restricted areas R-4806, R-4807, and R-4809.

DOE is the controlling authority for activities in restricted area R-4808, which is part of the Nevada Test Site. Restricted area R-4808 covers about 4,400 square kilometers (1,700 square miles) and consists of two areas, north (R-4808N) and south (R-4808S) (Figure 3-2). The Federal Aviation Administration has designated R-4808N as non-joint use. Portions of R-4808N overlay the footprint of the proposed repository. R-4808S is designated a joint-use area for the Nevada Test Site, Nellis Air Traffic Control Facility, and the Federal Aviation Administration Los Angeles Air Route Traffic Control Center to use on an as-needed basis.

Between the military operations area in California and the restricted airspace in Nevada, there is a corridor of Class A and Class G airspace that is used by commercial, military, and private aircraft (Figure 3-2). Within this corridor, there is airspace located within 1.6 kilometers (1 mile) from the planned repository surface facilities, bordered to the north and east by the DOE restricted airspace and to the south by the Class A and G airspace, that is designated a Low Altitude Tactical Navigation Area. This airspace is used by the U.S. Air Force for A-10 aircraft and helicopter flights. The Air Force makes approximately 30 flights weekly in this area. Other aircraft in this airspace generally consist of small piston-engine airplanes, helicopters, and gliders. *Identification of Airplane Hazards* discusses a ground survey of this area and concludes that there is little civilian air activity (DIRS 181770-BSC 2007, pp. 22 and 23).

3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality and climate is an area within a radius of approximately 80 kilometers (50 miles) around the Yucca Mountain site. This region encompasses portions of Esmeralda, Clark, Lincoln, and Nye counties in Nevada and a portion of Inyo County, California. To

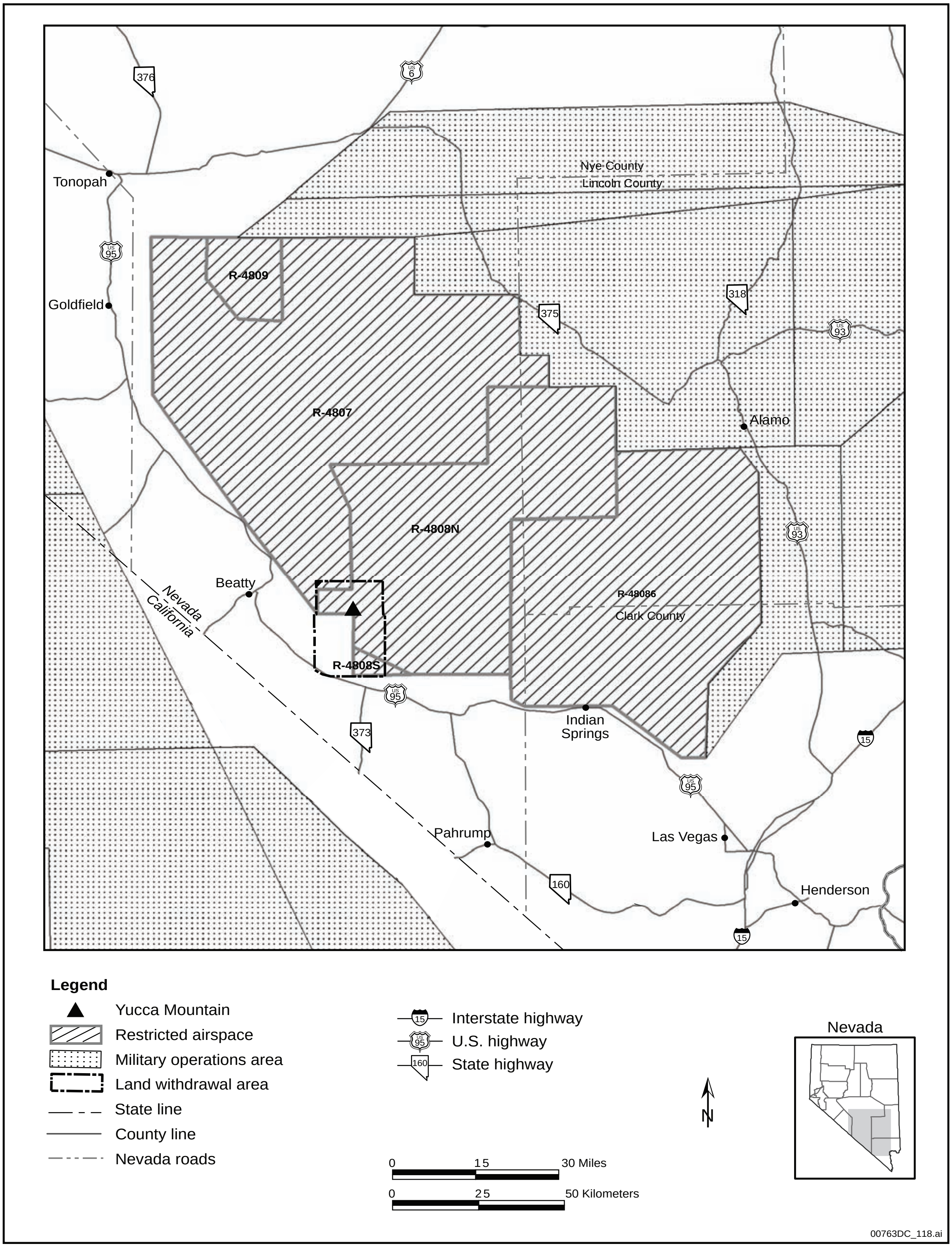


Figure 3-2. Airspace use near Yucca Mountain.

determine the air quality and climate for Yucca Mountain, DOE site characterization activities included *ambient air* and meteorological data collection. DOE has monitored the air for *criteria pollutants:* gases (*carbon monoxide, nitrogen dioxide, ozone*, and *sulfur dioxide*) and *PM_{10}*. PM_{10} is *particulate matter* with an aerodynamic diameter of 10 micrometers or less (about 0.0004 inch). This section summarizes, incorporates by reference, and updates Section 3.1.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-12 to 3-17).

AMBIENT AIR

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in immediate proximity to emission sources.

3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants (called criteria pollutants) in the atmosphere. The U.S. Environmental Protection Agency (EPA) established the National *Ambient Air Quality Standards*, as directed by the *Clean Air Act* (42 U.S.C. 7401 et seq.), to define the levels of air quality that are necessary to protect the public health (primary standards) and the public welfare (secondary standards) with an adequate margin of safety. The National Ambient Air Quality Standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

The criteria pollutants under the National Ambient Air Quality Standards are ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. The Nevada Administrative Code defines the Nevada standards of quality for *ambient* air for each criteria pollutant. The Nevada standards are the same as the National Ambient Air Quality Standards with the exception of a more restrictive carbon monoxide standard in locations with a ground elevation above 5,000 feet. The EPA designates an area as being in attainment for a particular pollutant if the concentration of that pollutant in ambient air is below the EPA standards. Areas in violation of one or more of these standards are called "*nonattainment areas*." If an area has not been designated as nonattainment and if there are no representative air quality data, the area is listed as "unclassifiable." For regulatory purposes, unclassifiable areas are considered to be in attainment. Section 176(c)(1) of the *Clean Air Act* requires federal agencies to ensure that their actions conform to applicable implementation plans for the achievement and maintenance of National Ambient Air Quality Standards for criteria pollutants. To achieve conformity, a federal action must not contribute to new violations of standards for ambient air quality, increase the frequency or severity of existing violations, or delay timely attainment of standards in the area of concern (for example, a state or a smaller air quality region). The EPA general conformity regulations (40 CFR 93, Subpart B) contain guidance for determination of whether a proposed federal action would cause emissions to be above certain levels in locations designated as nonattainment or maintenance areas. By definition, a "maintenance area" is a region that was previously in nonattainment, but that EPA or the state has redesignated as an attainment area with a requirement to develop a maintenance plan.

The Prevention of Significant Deterioration program of the *Clean Air Act* controls air quality in attainment areas; its goal is to prevent significant deterioration of existing air quality. This program is applicable only to point sources and does not apply to transportation sources. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Under this scheme, Class I allows very little deterioration of air quality, Class II allows moderate deterioration, and Class III allows more deterioration, but in all cases the pollution concentrations must not violate any National

Ambient Air Quality Standard. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less-restrictive class to acknowledge the value of maintaining these areas in relatively pristine condition. In addition, Congress protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only. All other areas were initially classified as Class II, with the possibility of redesignation as Class I or Class III.

The quality of the air at the Yucca Mountain site and the nearby parts of the Nevada Test Site, Nevada Test and Training Range (including southwestern Lincoln County), southwestern Esmeralda County, and southern Nye County within the air quality region of influence is unclassifiable because there are limited air quality data (40 CFR 81.329). However, the limited data collected at the site indicate that the air quality is within applicable National Ambient Air Quality Standards and is, therefore, in attainment.

While the air quality in most of Nye County is unclassifiable, a portion of Hydrologic Basin 162 (near the Town of Pahrump) has a maintenance status. Historical monitoring data since 2000 for PM_{10}, collected by the Nevada Division of Environmental Protection, documented exceedences of the National Ambient Air Quality Standards. Nye County and Pahrump, in cooperation with the Nevada Division of Environmental Protection, successfully negotiated with the EPA to enter into a Memorandum of Understanding. The Memorandum requires the parties to prepare a Clean Air Action Plan for the portion of Basin 162 within the Pahrump Regional Planning District, where rapid growth and development have affected air quality with increased fugitive dust levels. As required by the Memorandum, Nye County has enacted an ordinance to regulate construction and other ground-disturbing activities and has implemented a mandatory program of Best Practicable Methods for use on all ground disturbances of 0.5 acres or greater.

The portions of Clark County within the air quality region of influence are in attainment with National Ambient Air Quality Standards and Nevada standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. Portions of Inyo County in the air quality region of influence are in attainment with the national PM_{10} standard, but are in nonattainment with the more restrictive California standard (DIRS 179903-California Air Resources Board 2006, all). In the region of influence, all areas are designated Class II. One area, Death Valley National Park, is a protected Class II area. Death Valley National Park could be redesignated Class I, which would make the allowable deterioration less than that currently allowed. The nearest boundary of Death Valley National Park is approximately 35 kilometers (22 miles) southwest of the proposed Yucca Mountain site development areas.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major point source of air pollutants. At present, the proposed Yucca Mountain site development areas and the Nevada Test Site have no sources subject to those requirements.

DOE maintains an air quality operating permit from the State of Nevada. The permit places specific operating conditions on equipment such as generators and compressors that DOE used during site characterization and uses during current activities. These conditions include limiting the emission of criteria pollutants; defining the number of hours per day and per year a system is allowed to operate; and determining the testing, monitoring, and recordkeeping necessary for the system. Nevada renewed the air quality operating permit in 2006 (DIRS 179968-DeBurle 2006, all).

DOE began monitoring *particulate matter* with an aerodynamic diameter of 10 micrometers or less (PM_{10}) in 1989 as part of site characterization activities and later as part of the Nevada air quality operating permit requirements. Monitoring for PM_{10} continues even though it is no longer a requirement of the air quality operating permit. Concentration levels of PM_{10} remain well below applicable National Ambient Air Quality Standards (Table 3-2). From October 1991 through September 1995, DOE monitored gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. During air monitoring for gaseous pollutants, the concentration levels of each pollutant, except ozone, were well below applicable National Ambient Air Quality Standards and Nevada standards (Table 3-2). The maximum 1-hour ozone concentration was 80 percent of the National Ambient Air Quality Standard, which was revoked in 2005. An 8-hour ozone concentration was not measured. DOE did not monitor for particulate matter with an aerodynamic diameter of 2.5 micrometers (about 0.0001 inch) or less ($PM_{2.5}$) as part of site characterization. $PM_{2.5}$ is a subset of PM_{10} and was not regulated under the National Ambient Air Quality Standards until 1997. Sources of $PM_{2.5}$ include smoke, power plants, and gasoline and diesel engines.

3.1.2.2 Climate

The region around Yucca Mountain has a *dry, semiarid* climate, with annual precipitation totals that range between approximately 10 and 25 centimeters (4 and 10 inches). Mean nighttime and daytime air temperatures typically range from 22 to 34 degrees Celsius (°C) [72 to 93 degrees Fahrenheit (°F)] in the summer and from 2° to 10.5°C (34° to 51°F) in the winter. Temperature extremes range from -15° to 45°C (5° to 113°F). On average, the daily range in temperature change is about 10°C (18°F).

In the valleys, local topography channels airflow, particularly at night during stable conditions. With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Figure 3-3 shows the wind patterns in the vicinity of the proposed repository, and illustrates the fluctuations in data from different heights and times of day.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundance of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat.

Paleoclimatology

Paleoclimatology is the study of ancient climates by examination of biological and geological proxy indications of climatic conditions in the geologic past. The primary assumption to predict future climatic conditions in the Yucca Mountain region is that climate is cyclical and, therefore, a study of past climates provides an insight into potential future climates. Studies indicate that climatic conditions at Yucca Mountain, which therefore could occur in the future, fall into the following categories: (1) a warm and dry interglacial period similar to the present-day climate, (2) a warm and wet monsoon period characterized by hot summers and increased summer rainfall, and (3) a cool and wet glacial-transition period (DIRS 170002-BSC 2004, all). The interglacial period has the lowest annual precipitation and highest annual temperatures of the climate periods, and represents the current climate at Yucca Mountain.

Table 3-2. Comparison of criteria pollutant concentrations measured at the Yucca Mountain site with national, Nevada, and California ambient air quality standards.

Criteria pollutant	Primary and Secondary NAAQS (except as noted) Averaging period	Concentration[a]	Highest concentration measured at Yucca Mountain[b,c]	Nevada standards[d]	California standards[e]
Sulfur dioxide	Annual[f]	0.03 part per million	0.002	Same	None
	24-hour[g]	0.14 part per million	0.002	Same	0.04 part per million
Sulfur dioxide (secondary)	3-hour[g]	0.5 part per million	0.002	Same	None
PM_{10}[h]	24-hour[i]	150 micrograms per cubic meter	67	Same	50 micrograms per cubic meter
$PM_{2.5}$	Annual[j]	15 micrograms per cubic meter	NA[k]	None	12 micrograms per cubic meter
	24-hour[l]	35 micrograms per cubic meter	NA	None	No separate state standard
Carbon monoxide	8-hour[g]	9 parts per million	0.2	Same[m]	Same
	1-hour[g]	35 parts per million	0.2	Same	20 parts per million
Nitrogen dioxide	Annual[f]	0.053 part per million	0.002	Same	None
Ozone	8-hour[n]	0.08 part per million	NA	None	0.07 part per million
	1-hour[o]	None	0.096	0.12 part per million	0.09 part per million
Lead	Quarterly average	1.5 micrograms per cubic meter	NA	Same	1.5 micrograms per cubic meter for 30-day average

a. Source: 40 CFR 50.4 through 50.11.
b. Units correspond to the units listed in the concentration column.
c. Source: DIRS 155970-DOE 2002, p. 3-13.
d. Source: Nevada Administrative Code 445B.22097.
e. Source: DIRS 179903-California Air Resources Board 2006, all.
f. Average not to be exceeded in the period shown.
g. Average not to be exceeded more than once in a calendar year.
h. PM_{10} annual standard was revoked effective December 17, 2006. Available evidence does not suggest a link between long-term exposure to PM_{10} and health problems.
i. Number of days per calendar year exceeding this value should be less than 1.
j. Expected annual arithmetic mean should be less than the value shown.
k. No $PM_{2.5}$ monitoring data have been collected at Yucca Mountain. NAAQS regulations for $PM_{2.5}$ were not issued until 1997, which was after site characterization monitoring had finished. Ongoing monitoring for fugitive dust (PM_{10}) does not monitor for $PM_{2.5}$; $PM_{2.5}$ is created by fossil-fuel combustion and is not a major component of fugitive dust.
l. 98th-percentile value should be less than value shown. Effective December 17, 2006.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 5,000 feet above mean sea level and 6 parts per million at or above 5,000 feet; Nevada Administrative Code 445B.22097.
n. The 3-year average of the fourth-highest daily maximum 8-hour average must not exceed this amount.
o. As of June 15, 2005, the EPA revoked the 1-hour ozone standard in all areas except the 14, 8-hour ozone nonattainment Early Action Compact Areas (DIRS 181491-EPA 2007, all). None of the areas is in Nevada.

NA = Not available.
NAAQS = National Ambient Air Quality Standard.
PM_{10} = Particulate matter with an aerodynamic diameter of 10 micrometers or less.
$PM_{2.5}$ = Particulate matter with an aerodynamic diameter of 2.5 micrometers or less.

The following compares the three climate categories (DIRS 170002-BSC 2004, all; DIRS 161591-Sharpe 2003, all):

1. The warm and dry interglacial period would be similar to the present-day climate, which has a mean annual temperature of 13°C (55°F) and a mean annual precipitation of 12 centimeters (5 inches).

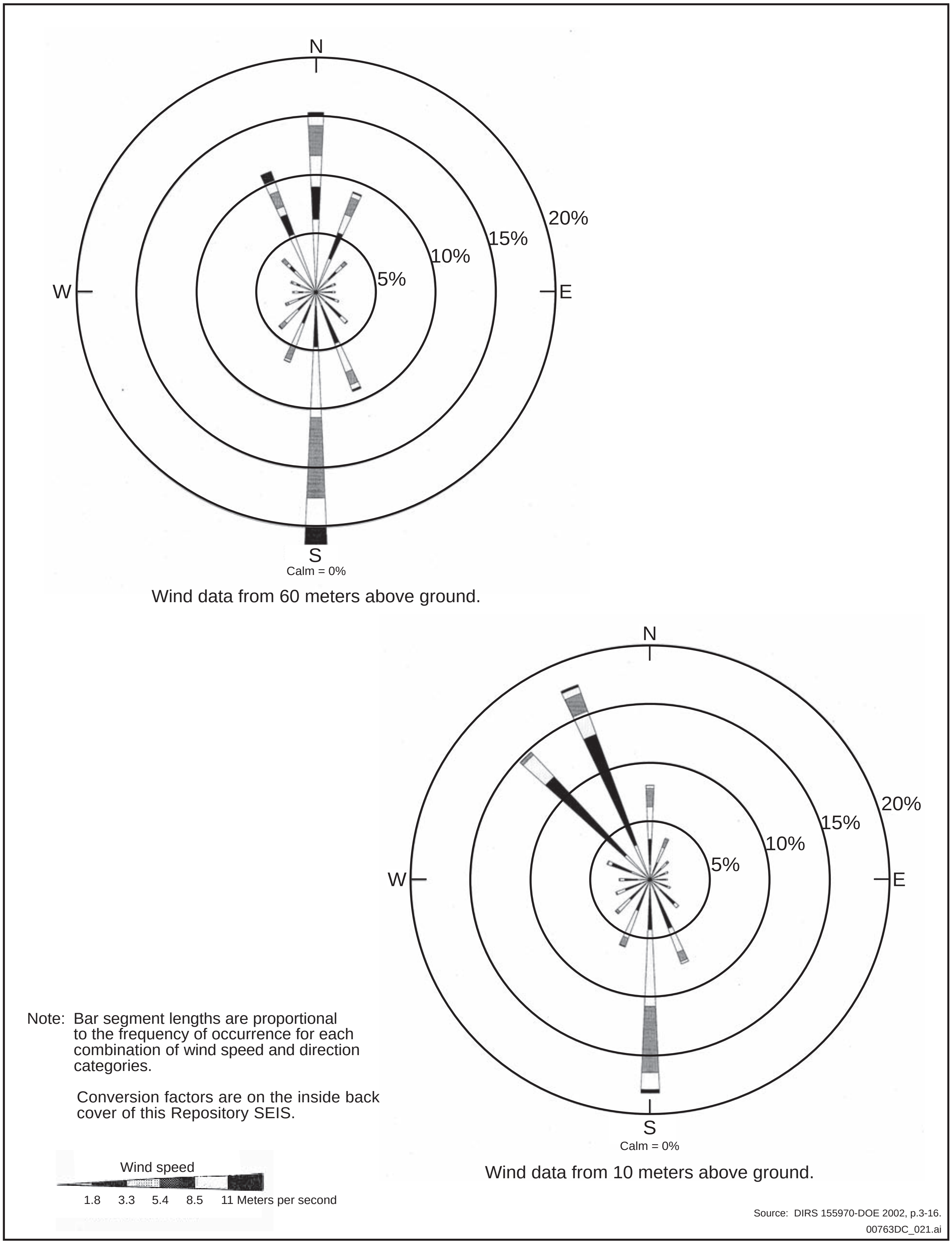


Figure 3-3. Wind patterns in the Yucca Mountain vicinity.

2. The warmer and wetter monsoon period would have mean annual temperatures that ranged from approximately 13° to 17°C (55° to 63°F) and a mean annual precipitation between 12 and 40 centimeters (5 and 16 inches).

3. The cooler and wetter intermediate glacial-transition period would have mean annual temperatures that ranged from approximately 8° to 10°C (46° to 50°F) and a mean annual precipitation between 20 and 45 centimeters (8 and 18 inches).

3.1.3 GEOLOGY

In the Yucca Mountain FEIS, DOE described the region of influence for geology as the physiographic setting (characteristic landforms), *stratigraphy* (rock strata), and geologic structure (structural features that result from rock deformations) of the region and of Yucca Mountain. DOE also addressed *seismicity* (*earthquake* activity) and volcanism in the Yucca Mountain region as geologic phenomena that could affect a repository. In addition, DOE described the potential for mineral and energy resources to occur at or near the site of the proposed repository. This Repository SEIS addresses the same region of influence and associated factors. This section summarizes, incorporates by reference, and updates Section 3.1.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-17 to 3-34) and presents new information, as applicable, from studies and investigations that have continued since completion of the Yucca Mountain FEIS.

Since 1997, Nye County, Nevada, has been performing investigations under a cooperative agreement with DOE to address technical issues and data gaps in the physical characterization of the land between Yucca Mountain and the potentially affected environment where Nye County residents live and work. These efforts, under Nye County's Independent Scientific Investigations Program and Early Warning Drilling Program, have included drilling of exploratory boreholes and monitoring wells, sampling of borehole cuttings and cores, and geologic and geophysical logging. DOE considered the information these programs gathered in the geology and hydrology discussions in the Yucca Mountain FEIS and has incorporated, as applicable, information it has collected since the completion of the Yucca Mountain FEIS into this Repository SEIS, particularly in the Section 3.1.4 hydrology discussion. More information on the Nye County programs is available from the County's Web site at http://www.nyecounty.com.

3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the *Great Basin*, which is characterized by generally north-trending, linear mountain ranges separated by intervening valleys, or basins. The mountain ranges are mostly the result of past episodes of faulting that resulted in the elevation differences between the ranges and the adjacent valleys. Erosion of the mountains filled the adjacent valleys with rock debris that ranges from very coarse boulders to sand and silt. Within this setting, Yucca Mountain is part of the southwestern Nevada volcanic field, a volcanic plateau formed between about 14 and 11.5 million years ago. As a result, Yucca Mountain is a product of both volcanic activity and faulting. Most of the volcanic rocks now at or near the surface of Yucca Mountain erupted from the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field), the remnants of which are north of Yucca Mountain.

In general, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle. The crest of Yucca Mountain reaches elevations from 1,500 to 1,900 meters (4,900 to 6,300 feet) above sea level, while the bottoms of the adjacent valleys are approximately 650 meters (2,100 feet) lower. Pinnacles Ridge borders the mountain on the north, Crater Flat is to the west, the *Amargosa Desert* is south, and the Calico Hills and Jackass Flats are on the east side. Figure 3-6 of the Yucca Mountain FEIS shows these and other physiographic features in the vicinity of Yucca Mountain. Crater Flat, which is between Bare Mountain to the west and Yucca Mountain to the east, contains four prominent volcanic cinder cones that rise above the valley floor. Jackass Flats is an oval-shaped valley surrounded (in a clockwise direction) by Yucca, Shoshone, Skull, and Little Skull mountains. Both Crater Flat and Jackass Flats drain southward to the *Amargosa River*. Drainage from Jackass Flats is via *Fortymile Wash*, a prominent drainage along the east side of Yucca Mountain.

3.1.3.1.1 *Site Stratigraphy and Lithology*

The rock strata, or *stratigraphic units*, in the region of Yucca Mountain are dominated by a thick series of volcanic rocks (including those of Yucca Mountain) that overlie much older sedimentary rocks of largely marine origin. Table 3-3 lists the generalized rock units of the region by the geologic age of their deposition. Only Tertiary Period and younger rocks are exposed at Yucca Mountain, but older rock units are exposed at Bare Mountain, the Calico Hills, and the Striped Hills, to the west, northeast, and southeast of Yucca Mountain, respectively. Detailed information about the characteristics of the older rocks beneath Yucca Mountain is sparse because only one borehole, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic Era carbonate rocks occur in this borehole at a depth of about 1,250 meters (4,100 feet).

Table 3-3. Highly generalized stratigraphy for the Yucca Mountain region.

Geologic age designation	Major rock types (lithologies)
Cenozoic Era Quaternary Period (less than 1.6 Ma)	Alluvium and colluvium; basalt.
Tertiary Period (less than 65 – 1.6 Ma)	Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the proposed repository).
Mesozoic Era (240 – 65 Ma)	Rocks of this age are of minor significance to the Yucca Mountain region. Small Mesozoic igneous intrusions are found near Yucca Mountain.
Paleozoic Era (570 – 240 Ma)	Three major lithologic groups (lithosomes) predominate: a lower (older carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian periods, a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian periods.
Precambrian Era (greater than 570 Ma)	Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline “basement.”

Source: DIRS 155970-DOE 2002, p. 3-21.
Ma = Approximate years ago in millions.

DOE has studied the Tertiary Period volcanic units in which it would emplace spent nuclear fuel and high-level radioactive waste at Yucca Mountain in great detail. These units consist mostly of tuffaceous rock, or tuff, which forms when a mixture of volcanic gas and ash violently erupts, flows, and settles in large sheets. The different volcanic units or layers are characterized based on changes in depositional features, the development of zones of welding and crystallization, and the development of alteration products in some rocks. DOE uses mineral and chemical composition and properties such as density and porosity to distinguish some units. Table 3-7 of the Yucca Mountain FEIS listed the units that form the

Tertiary volcanic rock sequence at Yucca Mountain from youngest (about 11.5 million years old) to oldest (more than 14 million years old) and provided characteristics of each. Tuffs of the Paintbrush Group, primarily bracketed by the Timber Mountain Group tuffs above and the Calico Hills Formation below, are of primary significance to the Proposed Action because of their proximity to the proposed repository *emplacement* level. At the base of the Paintbrush Group is the Topopah Spring Tuff, in which DOE tunneled the Exploratory Studies Facility and where the emplacement area would be. Figure 3-4 is a map of the general bedrock geology of the proposed repository location; the Yucca Mountain FEIS contained a similar figure. Figure 3-4 shows the updated shape and location of the repository outline (the proposed drift boundary). Figure 3-5 is a vertical cross-section through the southern part of the area in Figure 3-4. The cross-section shows the subsurface expression of the mapped units, including such structural aspects as the east-dipping rock units and the predominantly west-dipping normal *faults*.

The volcanic rock units in Figures 3-4 and 3-5 formed during the Tertiary Period and, although younger volcanic rocks occur locally in the Yucca Mountain vicinity, they are of limited extent and represent low-volume eruptions. The younger rock formations typically consist of a single main cone surrounded by a small field of basalt flows. Four northeast-trending cinder cones in the center of Crater Flat (to the west of Yucca Mountain) are primary examples of volcanic remnants that are younger than the Tertiary Period rock sequences. These four cinder cones are about 1 million years old. The youngest basaltic center in the vicinity is the 70,000- to 90,000-year-old Lathrop Wells center, a single cone about 16 kilometers (10 miles) south of the Yucca Mountain South Portal development area. The youngest stratigraphic units at Yucca Mountain are the surficial deposits shown in Figures 3-4 and 3-5 as alluvial (stream) and colluvial (hill slope) deposits.

3.1.3.1.2 *Selection of Repository Host Rock*

DOE based the selection of the repository emplacement area on several considerations: (1) depth below the ground surface sufficient to protect spent nuclear fuel and high-level radioactive waste from exposure to the surface environment, (2) extent and characteristics of the host rock, (3) location of major faults that could adversely affect the stability of underground openings or act as pathways for water flow, and (4) location of the *water table* in relation to (below) the proposed repository. Under the current repository design, DOE would use the same middle to lower portion of the Topopah Spring Tuff (Figure 3-5) for the emplacement area as the Yucca Mountain FEIS described.

Experience and information that DOE has gained from the excavation of the Exploratory Studies Facility, excavation of the Enhanced Characterization of the Repository Block *Cross-Drift*, and associated studies show this section of rock to meet the selection criteria. It has been demonstrated that stable openings can be constructed in this rock, that its thermal and mechanical properties enable it to accommodate the anticipated range of temperatures, that the location of the volume of rock necessary to host the repository is between faults with evidence of displacement during the Quaternary Period (that is, in the past 1.6 million years and, in this case, the faults are the major north-trending, block-bounding faults), and that the location of the water table is well below the selected repository horizon [160 to 400 meters (530 to 1,300 feet)].

3.1.3.1.3 *Potential for Volcanism at the Yucca Mountain Site*

There have been extensive investigations of the volcanic geology and stratigraphy at Yucca Mountain and the surrounding region, and DOE has used this information to evaluate the potential for future eruptions

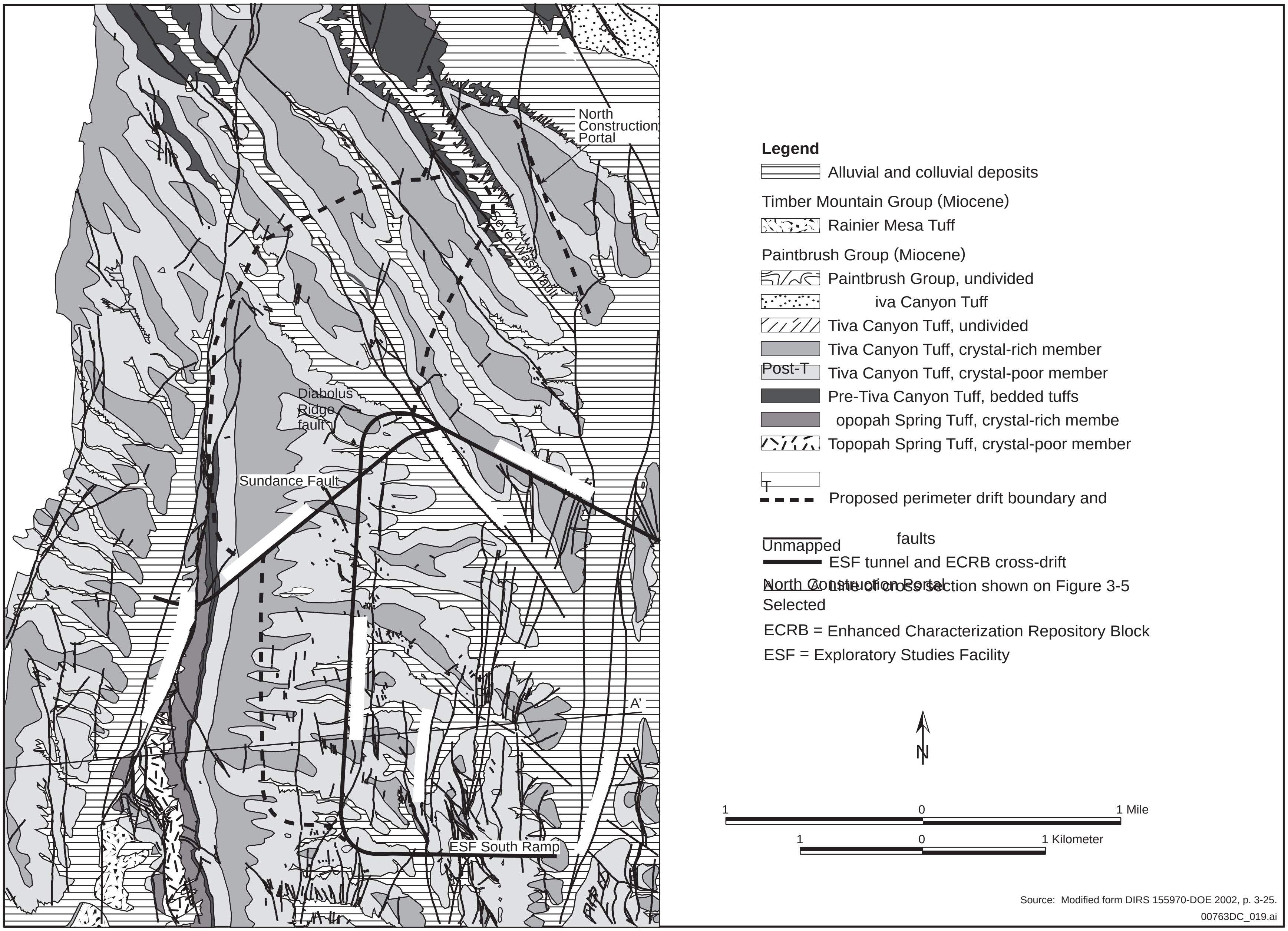
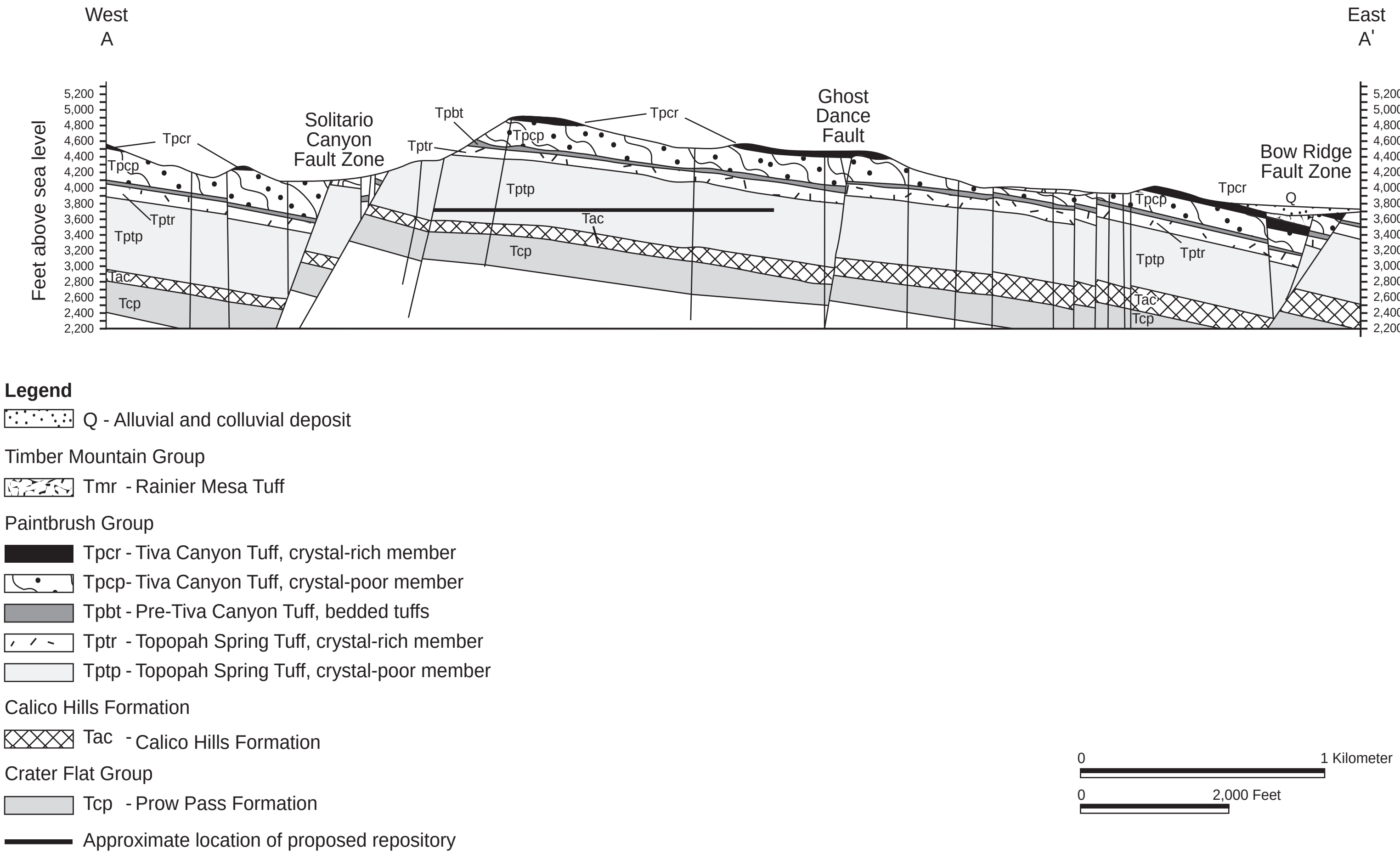


Figure 3-4. General bedrock geology of the proposed repository ·



Note: Line of cross section indicated on Figure 3-4.

Source: DIRS 155970-DOE 2002 p. 3-26.

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Figure 3-5. Simplified geologic cross section of Yucca Mountain, west to east.

to occur that could adversely affect long-term performance of the proposed repository. In 1995 and 1996, a panel of 10 recognized experts from federal agencies, national laboratories, and universities evaluated the potential for disruption of the repository by a volcanic intrusion, also known as a dike. The result of that effort was an estimate of the average probability of 1 chance in 7,000 that a volcanic dike could intersect or disrupt the repository during the first 10,000 years after closure. As the Yucca Mountain FEIS reported, DOE increased this probability to 1 chance in 6,300 to account for a slightly larger repository footprint than the expert panel considered (DIRS 155970-DOE 2002, p. 3-27). The likelihood of an intersection increases by small amounts if the footprint size increases because the larger area presents a larger "target" for the dike to intersect, should an event occur.

Since DOE completed the Yucca Mountain FEIS, the size and shape of the repository footprint has changed slightly, and so has the probability of a dike intersection. DOE based the new calculation on the work in 1995 and 1996 by the panel of experts. The estimated probability of a dike intrusion is now 1 chance in 5,900 during the first 10,000 years, with 5th- and 95th-percentile values of 1 chance in 133,000 and 1 in 1,800, respectively (DIRS 169989-BSC 2004, pp. 7-1 and 7-2, and Table 7-1).

DOE has collected additional aeromagnetic and ground magnetic data about the Yucca Mountain vicinity since 2002. As reported in *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (DIRS 169989-BSC 2004, p. 6-79), there were 20 to 24 identified magnetic anomalies in Crater Flat and northern Amargosa Valley. These anomalies could represent buried basaltic volcanoes. At the time, the expert elicitation effort of 1995 and 1996 knew of eight of these anomalies and included them in the evaluations. DOE evaluated the effect of the additional anomalies on the probability calculations for a volcanic dike intersection. Using several assumptions, which included that the anomalies actually represent basaltic volcanic centers, the mean annual frequency of intersection could increase (DIRS 169989-BSC 2004, pp. 6-79 to 6-83). In 2004, DOE completed a high-resolution aeromagnetic survey, then initiated a drilling program in the areas of the anomalies to determine the age and other characteristics of any encountered basalts. At the time of the 2005 technical article, "Uncovering Buried Volcanoes at Yucca Mountain" (DIRS 177379-Perry et al. 2005, all), three holes were complete. Two encountered basalt, but the third did not. DOE is conducting an update of the 1995 and 1996 expert elicitation to review and interpret the new information. For the analysis used in this Repository SEIS, the Department continues to use the information derived from the 1995 and 1996 panel of experts.

3.1.3.2 Geologic Structure

Geologic structures, such as folds and faults, result from the deformation of rocks after their original formation. The Yucca Mountain FEIS discussed the north-trending, block-bounding faults that crustal extension has formed during the last 20 million years and the intrablock and subsidiary faults that occur between the block-bounding faults. The estimated total displacement along the major block-bounding faults in the Yucca Mountain region during the last 12 million years ranges from less than 100 to more than 500 meters (330 to 1,600 feet). Displacements on these faults during the Quaternary Period (the last 1.6 million years) range from 0 to 6 meters (0 to 20 feet), with most about 1 to 2.5 meters (3.3 to 8.2 feet). In terms of the amount of movement per seismic event, the block-bounding faults of primary significance to Yucca Mountain have moved from 0 to 1.7 meters (0 to 5.6 feet) per event. The Solitario Canyon Fault along the west side of Yucca Mountain and the Bow Ridge Fault along the east side are the major block-bounding faults that bracket the emplacement area. Within this block, there is no clear evidence of any Quaternary movement along the intrablock and subsidiary faults (that is, the age of the last movement along these intrablock and subsidiary faults is either pre-Quaternary or undetermined).

In addition to rock *fractures* from faulting, there are fractures (or joints) in the rock at Yucca Mountain where there has been no displacement of the sides in relation to each other. These joints are divided into different types based on how and when they form. The Yucca Mountain FEIS described early cooling joints, later tectonic joints, and joints due to erosional unloading. Joints do not typically form through-going features like faults, but do have geoengineering aspects (those in relation to rock excavation) and hydrologic aspects (groundwater movement in rock) that DOE considered in the repository performance analysis.

The Yucca Mountain FEIS provided details on the geologic structure of the Yucca Mountain region and the location of the proposed repository. This information included a figure that showed the locations of the major faults at Yucca Mountain superimposed on the outline of the repository emplacement area and a list of major faults by name, with descriptions and summaries of displacement characteristics.

3.1.3.3 Modern Seismic Activity

The Yucca Mountain FEIS described the nature of seismic activity at the Nevada Test Site since 1978 and included a description of the largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain, which was the Little Skull Mountain earthquake in 1992 about 20 kilometers (12 miles) southeast of Yucca Mountain. This seismic event had a Richter scale magnitude of 5.6 and was apparently triggered by a 7.3-magnitude earthquake at Landers, California, 300 kilometers (190 miles) to the south of Yucca Mountain, which occurred 20 hours earlier (DIRS 169734-BSC 2004, p. 4-38). The Little Skull Mountain event caused no damage at Yucca Mountain, but some damage did occur at the Field Operations Center in Jackass Flats about 5 kilometers (3 miles) north of the epicenter.

Since completion of the Yucca Mountain FEIS, another earthquake occurred at Little Skull Mountain (magnitude 4.4) in June 2002 within the aftershock zone of the 1992 earthquake (DIRS 172053-von Seggern and Smith 2003, pp. 20 and 25). There are no known reports of damage to facilities or changes in the subsurface rock at Yucca Mountain from the June 2002 event. The 1992 event is still the largest recorded event within 50 kilometers (30 miles) of Yucca Mountain.

Seismic Hazard

The Yucca Mountain FEIS described DOE’s effort to use historical records of earthquakes, evidence of prehistoric earthquakes, and observed ground motions during modern earthquakes to predict the nature and frequency of future seismic events at Yucca Mountain. The Department convened two panels of scientific experts, one to characterize future earthquakes in relation to the potential for surface fault displacement and the other to consider the associated ground motion and how it would diminish with distance. The *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada* (DIRS 100354-USGS 1998, all) provided the results of the two-panel effort and resulted in the preliminary bases for the design of facilities at Yucca Mountain and for forecasting elements of the repository’s long-term performance in the Yucca Mountain FEIS. Key conclusions, which DOE has carried into subsequent evaluations (DIRS 173247-BSC 2005, pp. 6-20 to 6-27 and 6-97 to 6-99), include estimates of annual probabilities for different fault displacements and ground motion magnitudes that could occur at Yucca Mountain as a result of seismic events. For example, a conclusion reached by the analyses (as the Yucca Mountain FEIS described) is that faults, other than major block-bounding faults, are likely to experience displacement of more than 0.1 centimeter (0.04 inch) less than once in 100,000 years.

The Yucca Mountain FEIS noted that DOE needed to complete additional investigations of ground motion site effects before development of a final seismic design basis for the surface facilities. Since the completion of the FEIS, DOE has continued its seismic investigations and evaluations and has developed numerous reports and models. Efforts include development of a site response model that incorporates effects of earthquake ground motion on the 300 meters (1,000 feet) of rock above the emplacement area of the proposed repository as well as for soil and rock beneath the surface facilities (DIRS 170027-BSC 2004, p. vi); that is, rather than estimating only the ground motion for a reference rock outcrop at Yucca Mountain, the model extends predicted effects to all areas where DOE would locate project structures, systems, and components determined to be important to safety. The *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain* (DIRS 170564-BSC 2004, p. 30) documents the methodology for the repository seismic design and describes the adoption of applicable seismic design procedures, acceptance criteria, codes, and standards that nuclear power plants use. This report indicates that the application for construction authorization will include the final seismic inputs for the design (DIRS 170564-BSC 2004, p. 3).

The Yucca Mountain FEIS discussion of seismic hazard referenced a study in *Science* magazine that reported unusually high crustal strain rates in the Yucca Mountain area (DIRS 103485-Wernicke et al. 1998, all). The article concluded that, if these high strain rates were correct, DOE's analysis could underestimate the potential for volcanic and seismic hazards. As the Yucca Mountain FEIS described, DOE continued its investigations on the crustal strain rate in the Yucca Mountain region through a grant to the University of Nevada and with an improved array of geodetic monitoring stations. In an article in the *Journal of Geophysical Research* (DIRS 175199-Wernicke et al. 2004, Abstract), the authors concluded that the high crustal strain rates between 1991 and 1997 were associated with the 1992 Little Skull Mountain earthquake. They noted that the strain rates from after 1998 (specifically from 1999 to 2003) did not appear to show an effect due to the earthquake and were notably lower. However, the lower strain rates were still higher than geologic predictions; that is, the geodetic estimates of deformation rates were not consistent with the low magnitude of Quaternary Period displacement that generally occurs in faults at Yucca Mountain. The findings of an independent interpretation of the geodetic information by University of Nevada researchers supported this conclusion (DIRS 180378-Hill and Blewitt 2006, all). In addition, this later effort suggested the possibility that the higher-than-expected strain rates might be due to relaxation of geologic features from a number of past earthquakes. DOE installed several new network stations in 2005 and, according to Hill and Blewitt, continued monitoring could help to test alternative scenarios for the cause of this apparent inconsistency. The continuing question is whether the strain rates and their cause can be shown to be consistent with DOE's conceptual model for seismic activity at the Yucca Mountain site or if the model needs adjustment. The recent findings have put the measured strain rates closer to expectations, but questions remain.

3.1.3.4 Mineral and Energy Resources

The Yucca Mountain FEIS described the concern that the analyzed Yucca Mountain land withdrawal area could have the potential for mineral resources that could lead to future exploration and inadvertent human intrusion into the repository. The Yucca Mountain FEIS also described DOE's efforts to investigate that potential and the resultant conclusion that the potential for economically useful mineral or energy resources within a conceptual *controlled area* around Yucca Mountain is low.

The Cind-R-Lite quarry is a mineral extraction operation (Section 3.1.1.2), that is outside the land area DOE evaluated for mineral resources, but it is inside the analyzed land withdrawal area. This operation is at a volcanic cinder cone approximately 10 kilometers (6 miles) northwest of the Town of Amargosa Valley, just north of U.S. Highway 95, and includes the mining of cinder for the manufacture of light-weight, high-strength cinder blocks. As described in Section 4.1.1, this operation is on a patented mining claim, which is private property, and would not be affected by the land withdrawal action; that is, it would remain in operation.

3.1.4 HYDROLOGY

In the Yucca Mountain FEIS, DOE described the region of influence for hydrology in terms of surface water and groundwater. The region of influence for surface water included areas of land disturbance that could be susceptible to erosion, areas that permanent changes in surface-water flow could affect, and areas downstream of the proposed repository that eroded soil or potential spills of contaminants could affect. The groundwater region of influence included aquifers that underlie areas of construction and operations, aquifers that could be sources of water for construction and operations, and aquifers downgradient of the proposed repository that repository use could affect, which included long-term releases of radioactive materials. This Repository SEIS addresses the same regions of influence. This section summarizes, incorporates by reference, and updates Section 3.1.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-34 to 3-69) and provides new information, as applicable, from studies and investigations that continued after completion of the FEIS.

In its introduction to hydrology, the Yucca Mountain FEIS described several key characteristics of the hydrologic system of the Yucca Mountain region of influence, which included its very dry climate, limited surface water, high potential evaporation, and deep aquifers. Yucca Mountain is in the Death Valley regional groundwater flow system (or simply Death Valley region) where the floor of Death Valley is the regional hydrologic sink and both surface water and groundwater generally do not leave except by *evapotranspiration*. Because there are no changes to the information, this Repository SEIS incorporates by reference the more detailed discussion in the Yucca Mountain FEIS of the key characteristics of the hydrologic system in the Yucca Mountain region.

3.1.4.1 Surface Water

3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which has few perennial streams and other surface-water bodies. The Amargosa River and its tributaries, which are dry along most of their lengths, drain Yucca Mountain and surrounding areas. The exceptions are short stretches of the river channel that are fed by groundwater discharges (that is, springs and seeps). The Amargosa River drainage terminates in the Badwater Basin in Death Valley. The nearest surface-water impoundments to Yucca Mountain are several ponds and reservoirs in the Ash Meadows National Wildlife Refuge, approximately 50 kilometers (30 miles) to the southeast. The impoundments and springs in the Ash Meadow area drain to the Amargosa River through Carson Slough.

The Amargosa River is an interstate water because it flows from Nevada into California and at least some portions of this ephemeral stream could be classified as waters of the United States as defined in 33 CFR Part 328 and regulated under Section 404 of the *Clean Water Act* (33 U.S.C. 1251 et seq.). Fortymile Wash, a tributary of the Amargosa River, and some of its tributaries in and near the *geologic repository operations area* might also be waters of the United States. On June 5, 2007, the EPA and the U.S. Army

Corps of Engineers released interim guidance that addresses the jurisdiction over waters of the United States in light of recent Supreme Court decisions. Based on this new guidance, it is less likely that the ephemeral washes and riverbeds in this area would be considered waters of the United States. However, for construction actions proposed in these washes, the Corps of Engineers would still have to determine the limits of jurisdiction under Section 404 of the *Clean Water Act*.

3.1.4.1.2 *Yucca Mountain Surface Drainage*

This section summarizes occurrences of past floods and the DOE evaluation of flood potential in the areas DOE would use for the Proposed Action.

Occurrence

There are no perennial streams, natural bodies of water, or naturally occurring wetlands in the analyzed land withdrawal area. Several named washes on the east side of Yucca Mountain drain into Fortymile Wash, as shown in Figure 3-6 (along with estimated flood zones). Solitario Canyon Wash collects drainage from the west side of Yucca Mountain. Both the west and east sides of Yucca Mountain drain into the ephemeral Amargosa River. Washes at Yucca Mountain carry water only in response to intense precipitation events and rapid snowmelt. Instances in which a large portion of the drainage system carries water at the same time are infrequent because they require the generation of runoff over a large area at the same time, and intense precipitation events in this region are generally confined to small areas. In March 1995 and February 1998, Fortymile Wash and the Amargosa River flowed simultaneously through their primary channels to Death Valley. The 1995 event represented the first documented case of this flow condition. Although not documented, similar incidents probably occurred during the preceding 30 years when there were several instances for which records show sections of the primary channels flowing with floodwater.

Flood Potential

Although water flow in washes at Yucca Mountain is an unusual occurrence, flooding can occur as a result of intense summer thunderstorms or sustained winter precipitation. As a result, DOE has used several different, recognized methodologies to calculate estimates of predicted flood levels, which include a probable maximum flood. Figure 3-6 shows these flood levels. The three flood levels for each of the prominent washes are the 100-year, 500-year, and regional maximum floods. The 100-year flood is of a magnitude that is likely to occur, on average, only once every 100 years. This means there is a probability of 0.01 that a flood of this size would occur in any one year. A 500-year flood would be likely to occur, on average, only once in 500 years and there would be a probability of 0.002 that it would occur in any one year. The regional maximum flood is yet a larger flood that considers size of the extreme floods that occur elsewhere in Nevada and in nearby states.

Figure 3-6 also shows the results of a fourth flood level estimate using the probable maximum flood method, which is based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all) and is considered the most severe reasonably possible flood. DOE calculated potential flood levels for the probable maximum flood only for specific locations on certain washes (the isolated segments of dark shading in Figure 3-6). The Department selected these specific locations for the calculations to verify that specific repository features, which would include the openings to the subsurface, would not be in the inundation zone of the probable maximum flood. This flood calculation incorporated the effects of mud and debris the flood would carry,

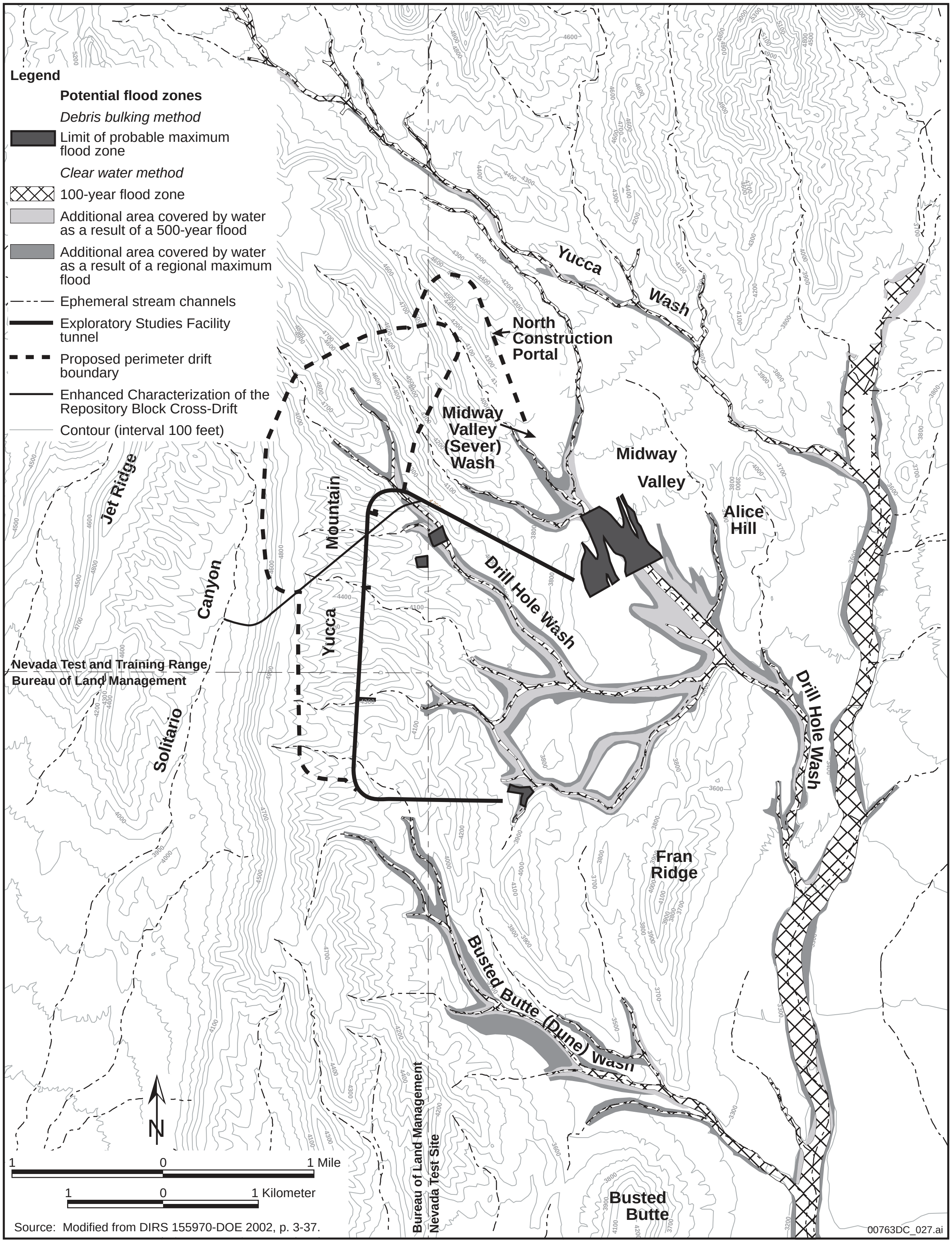


Figure 3-6. Site topography and potential flood areas.

which would significantly increase the volume of the flood flow and the lateral extent of area it would cover.

The flood levels in Figure 3-6 are the same as those in the Yucca Mountain FEIS. The FEIS also presented estimates of the peak discharges due to these the flood levels. Appendix C of this Repository SEIS is a floodplain and wetlands assessment DOE prepared that further addresses flooding issues in relation to the ephemeral washes at Yucca Mountain.

Surface-Water Quality

DOE has collected stream water samples (at times of flow) at and near Yucca Mountain for comparison with groundwater samples. The Department analyzed these samples for general chemical characteristics (that is, mineral content) and summarized the results in the Yucca Mountain FEIS. Groundwater samples contained a higher mineral content than stream samples, which suggests more interaction between the rock and water.

3.1.4.2 Groundwater

This section discusses groundwater first in the region, in general, then more specifically at Yucca Mountain. Section 3.1.4.2 of the Yucca Mountain FEIS discussed differences of opinion on the groundwater system (DIRS 155970-DOE 2002, pp. 3-39 to 3-69).

3.1.4.2.1 *Regional Groundwater*

Yucca Mountain is in the Death Valley region, which is complex, with many aquifers and confining units that can vary greatly in their characteristics over distance. In some areas, confining units allow movement between aquifers, and in other areas they can be sufficiently impermeable to support artesian conditions where water will rise in a well to a higher elevation than that first encountered. In general, the principal water-bearing units in the Death Valley region can be classified as volcanic aquifers, alluvial aquifers, and carbonate aquifers. The mountainous areas in the north-central portion of the Death Valley region are mostly of volcanic origin and contain associated volcanic aquifers. Alluvial aquifers occur in the basin-fill areas between mountains and include the large Amargosa Desert (Figure 3-7). This discussion uses "alluvial aquifers" as a simplification for the basin- or valley-fill materials specific to the Amargosa Desert. Studies by the U.S. Geological Survey (DIRS 173179-Belcher 2004, all) and by Nye County (DIRS 156115- Nye County Nuclear Waste Repository Project Office 2001, all) identify multiple units in their characterizations of these basin-fill materials. The hydrogeologic framework model the Survey developed describes the unconsolidated basin-fill sediments as including two alluvial aquifers, two alluvial confining units, an interfingered limestone aquifer, and two volcanic units (DIRS 173179-Belcher 2004, pp. 39 and 40). These units differ in their makeup and in their manner of deposition, as well as in their hydraulic parameters. In this discussion, alluvial aquifer refers to the various unconsolidated materials in the Amargosa Desert through which groundwater moves. DOE recognizes that this portion of the groundwater flow path has a complex geology.

The carbonate aquifers are regionally extensive, and in the immediate area of Yucca Mountain occur at great depths below the volcanic and alluvial aquifers. Carbonate rocks occur at widely different depths throughout the Death Valley region, including at the surface, and often are very thick in a particular location. Carbonate rocks are often characterized as the most permeable rocks in the region; the permeability is due primarily to fractures, faults, and solution channels (DIRS 173179-Belcher 2004,

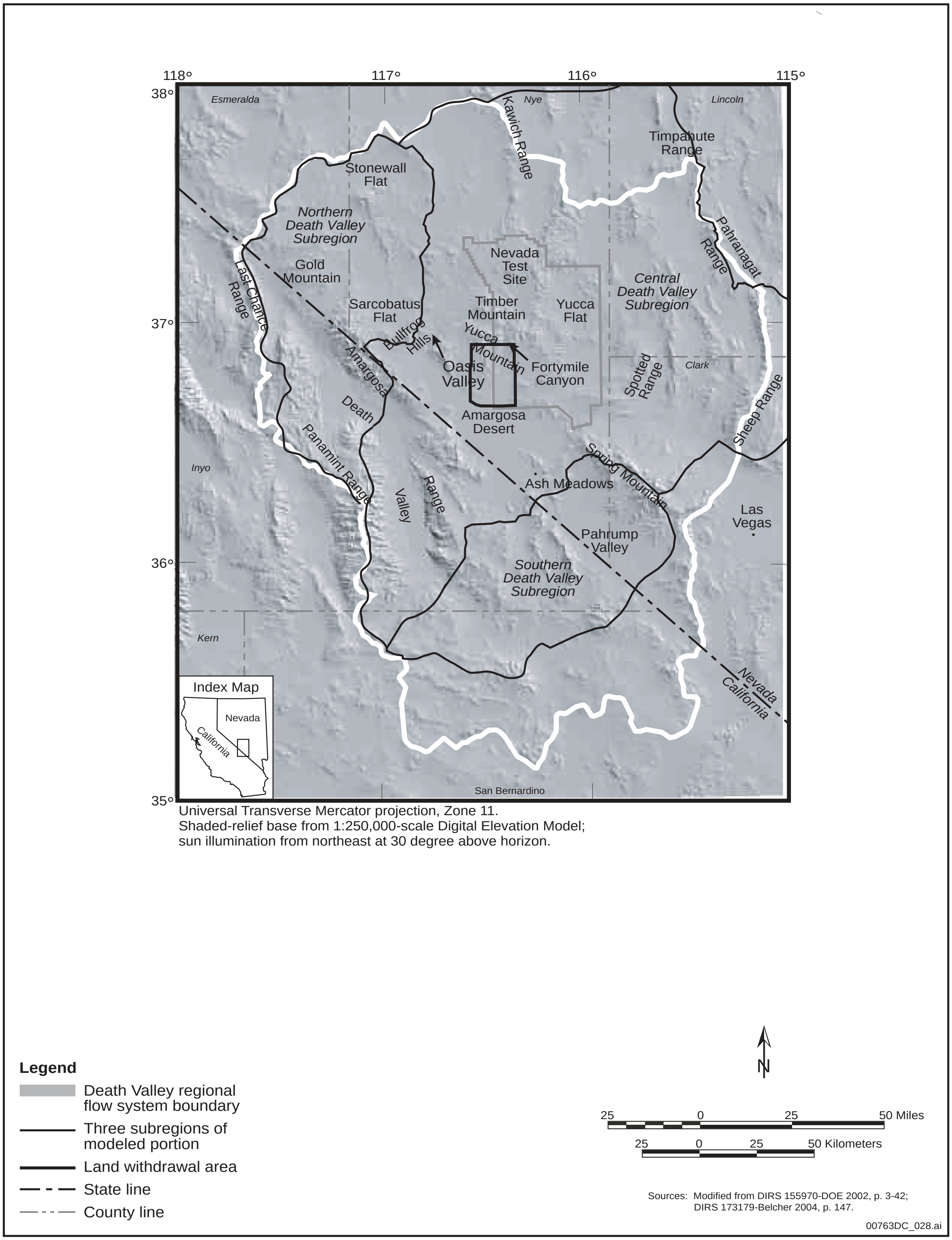


Figure 3-7. Boundaries of Death Valley regional groundwater flow system.

p. 65). However, these rocks formed during the Paleozoic Era (Table 3-3) and have been subject to a long, complex history of tectonic activity (DIRS Nye County Nuclear Waste Repository Project Office - NWRPO 2001, p. F53) and associated structural deformations. Although carbonate aquifers are regionally extensive, they are not necessarily extensively interconnected and often occur in compartments (DIRS Nye County Nuclear Waste Repository Project Office -NWRPO 2001, p. F53) that might or might not have a hydraulic connection to the carbonate rock in an adjacent compartment. When hydraulically connected, carbonate aquifers provide a path for flow between groundwater basins (DIRS 173179-Belcher 2004, p. 65).

The alluvial aquifers below the Amargosa Desert receive underflow from groundwater basins to the east and the north, including the aquifers that underlie Yucca Mountain. Deep drill holes indicate the presence of a carbonate aquifer below Yucca Mountain that extends into the Amargosa Desert. Groundwater flow in the northwest Amargosa Desert is generally to the southeast toward the central part of the basin and then southward toward the discharge area at Alkali Flat with some of the flow perhaps moving into Death Valley. In contrast, flow in the southeastern portion of Amargosa Desert is generally to the west and southwest. Some of the flow in the southeast part of Amargosa Desert discharges via springs and evapotranspiration at the Ash Meadows area. The remainder of the flow from the east merges with the mores southerly flow in the south-central portion of Amargosa Desert and continues toward Alkali Flat.

Basins

Studies of the Death Valley region often divide the area into the Northern, Central, and Southern Death Valley subregions (Figure 3-7). As shown in Figure 3-8, the Central subregion, which contains Yucca Mountain, is further divided into three groundwater basins: (1) Pahute Mesa-Oasis Valley, (2) Ash Meadows, and (3) Alkali Flat-Furnace Creek. The Yucca Mountain FEIS discussed each of these basins in detail, which included the identification of areas of recharge and discharge (if any), the general direction of groundwater flow, and where subsurface flow leaves the basin. The remaining information in this section, as summarized from the Yucca Mountain FEIS, focuses on the Alkali Flat-Furnace Creek groundwater basin, which the Proposed Action could affect the most.

Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin, so named because of the evidence that the groundwater in this basin discharges mainly at Alkali Flat (also known as Franklin Lake Playa) and potentially to the Furnace Creek area of Death Valley (Figure 3-8). Fortymile Wash and precipitation that infiltrates the surface are sources of recharge in the immediate vicinity of Yucca Mountain, but the primary sources of recharge to the Alkali Flat-Furnace Creek groundwater basin are the high mountains to the north, south, and southwest of Yucca Mountain, across the Amargosa Desert. Water that infiltrates at Yucca Mountain joins with water in the Fortymile Canyon section of the basin (Figure 3-8) and flows south to the Amargosa Desert and a primary discharge area of Alkali Flat, with some flow potentially moving into Death Valley along the same general course followed by the Amargosa River channel (DIRS 173179-Belcher 2004, pp. 155 and 156). DOE has developed and recently updated a model of net infiltration for the Yucca Mountain site (DIRS 174294-SNL 2007, all) (Section 3.1.4.2.2). As for the Yucca Mountain FEIS, estimates from this infiltration model are directly comparable with published estimates of the amount of water that moves through the Amargosa Desert to reach a conclusion that contributions from recharge at Yucca Mountain would be a very small percentage of the total flow. DOE has performed modeling studies of the saturated zone groundwater flow path from Yucca Mountain and estimated it would take 810 years for 50 percent of a conservative, nonsorbing radionuclide in the absence of decay added to groundwater beneath Yucca Mountain to travel

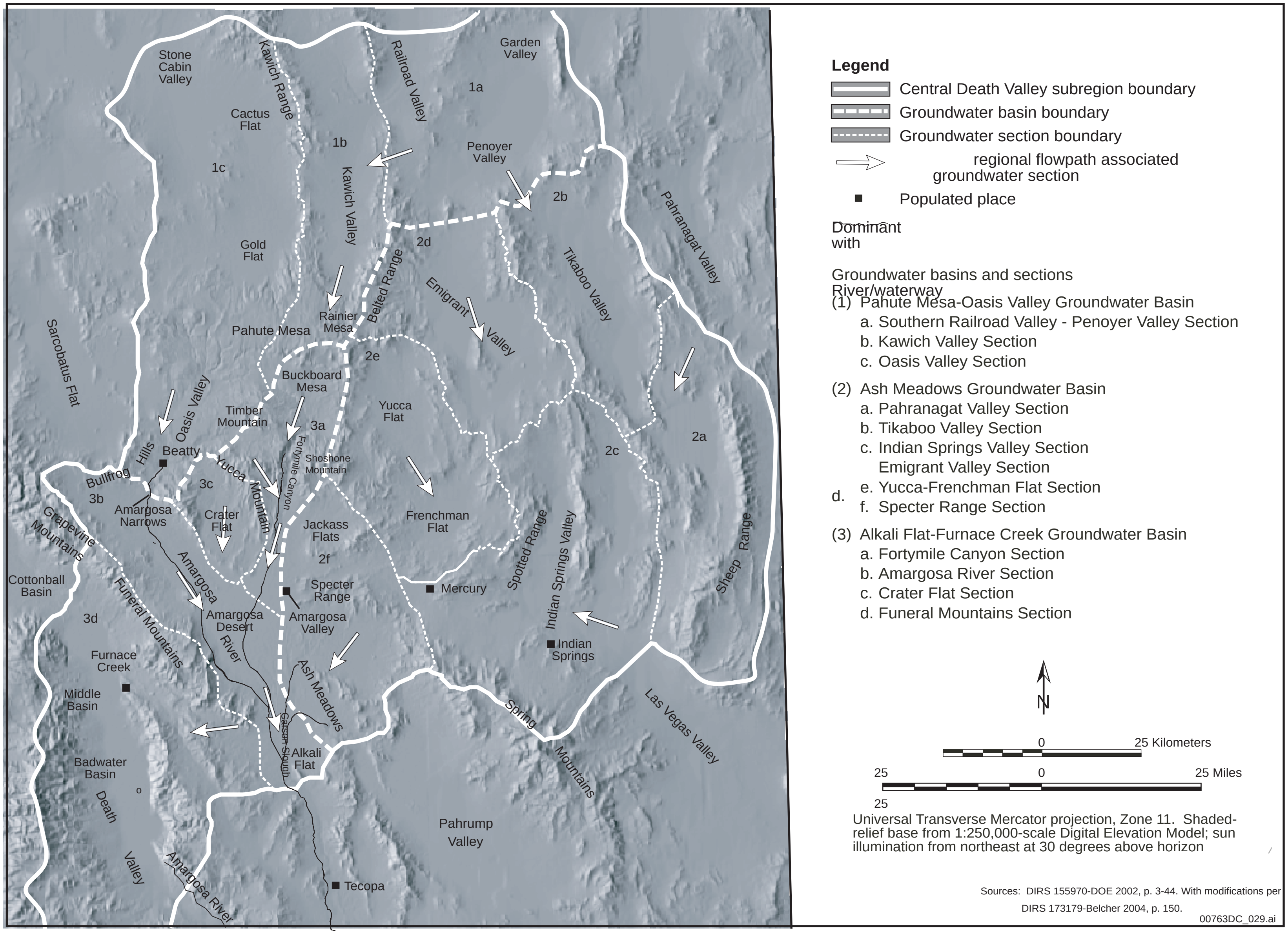


Figure 3-8. Groundwater basins and sections of the Central Death Valley subregion.

18 kilometers (11 miles) along the flow path. Some of the tracer would reach that distance faster, but half would take longer (DIRS 177392-SNL 2007, p. 6-41).

As groundwater in the Alkali Flat-Furnace Creek groundwater basin moves south beneath the Amargosa Desert, underflow from the Ash Meadows groundwater basin joins it. A line of springs fed by Ash Meadows basin groundwater marks a portion of the boundary between the two basins and supports habitat in the Ash Meadows National Wildlife Refuge. Devils Hole, a groundwater-filled cave in a fault zone, is in this area. As the Yucca Mountain FEIS noted, there is evidence that the carbonate aquifer feeds the line of springs in the Ash Meadows area. In this area, there is a relatively sharp decrease in groundwater head, or elevation, from east to west, so it is clear that groundwater at Ash Meadows moves into the Alkali Flat-Furnace Creek basin rather than the opposite.

The Yucca Mountain FEIS described studies that DOE and others have initiated to reduce uncertainties about the regional groundwater flow system, particularly studies by Nye County under a cooperative agreement with DOE. Since the completion of the Yucca Mountain FEIS, DOE has established a similar program with Inyo County in California. The Department has obtained new borehole data and other information from these ongoing county efforts (DIRS 180739-Williams 2003, p. A-4) and incorporated them in the regional hydrogeologic framework model, which the U.S. Geological Survey developed (DIRS 173179-Belcher 2004, all) and which continues to evolve, to simulate groundwater conditions and movement in the Death Valley region. A primary change to the model since the completion of the Yucca Mountain FEIS is characterization of the depth and extent of the alluvial layers and the alluvial aquifer in the area south of Yucca Mountain (DIRS 180739-Williams 2003, p. 2-39), which is the focus of the Nye County drilling program. A recent update to the hydrogeologic framework model (DIRS 174109-SNL 2007, all) includes data collected through Phase IV of the Nye County program. One of the many objectives of the Nye County program has been to locate the tuff-alluvium contact—the zone where water moving south from Yucca Mountain changes from primarily flowing in the fractured rock of the volcanic aquifer to dispersed flow through the relatively porous material of the alluvial aquifer. The Nye County report on its Phase IV drilling program interprets the Highway 95 Fault as the southern boundary of the volcanic aquifers (DIRS 182194- Nye County Nuclear Waste Repository Project Office 2005, p. 70). The Highway 95 Fault is a Tertiary fault that roughly aligns with U.S. Highway 95 in the area where Fortymile Wash enters the Amargosa Desert. Drilling results show volcanic aquifers on the north side of the fault that line up with older Tertiary sedimentary rocks on the south side. Nye County further speculated that contact with the less permeable Tertiary rock forces the southward groundwater flow up into the overlying alluvial aquifer system, which continues into lower Fortymile Wash and the Amargosa Desert (DIRS Nye County Nuclear Waste Repository Project Office -NWRPO 2005, p. 70). These and other updates to the hydrogeologic framework model have resulted in an increasingly more realistic representation of the groundwater flow system, which supports a more detailed understanding of the potential long-term effects of the Proposed Action.

DOE has incorporated hydrogeologic information collected by Nye and Inyo counties into studies to define groundwater flow paths based on naturally occurring chemical and isotopic constituents in the water. Chloride and sulfate are primary examples of the chemical constituents under study, and deuterium (hydrogen-2) and oxygen-18 are examples of isotopes the studies are tracking. The concentrations of these constituents in groundwater depend on parameters such as the location and time the water first infiltrated from the surface, the rock materials it passed through on its route and the resulting rock-water interactions, and the mixing that has occurred in the groundwater. Groundwater samples from different locations have different chemical signatures that reflect individual *pathway* histories (DIRS 180739-Williams 2003, p. 2-17). The regional groundwater flow paths that these geochemical signatures identify are consistent with the general flow directions that were developed from the potentiometric surface of the groundwater (DIRS 180739-Williams 2003, p. 2-25), as summarized above and described in more detail in the Yucca Mountain FEIS.

A primary focus of the Inyo County efforts has been the investigation of the source of the water that discharges from the various springs on the east side of Death Valley and whether there is a hydraulic connection between those springs and the groundwater moving beneath Yucca Mountain. One finding of interest from the geochemical observations involves the source of the water that moves beneath the Funeral Mountains to discharge points in the Furnace Creek area of Death Valley. The chemical and isotopic characteristics of the Death Valley discharges are similar to those in the Ash Meadows basin and dissimilar in several chemical concentrations to groundwater from the alluvial aquifer in the Amargosa Desert. This suggests that the deep underflow of groundwater from the underlying carbonate aquifer (rather than the alluvial aquifer in the Amargosa Desert) that contributes to discharges in the Ash Meadows area is the primary source of the spring discharge in Death Valley (DIRS 180739-Williams 2003, p. 2-21). This implies a westward component of flow in the underlying carbonate aquifer in this area of the Amargosa Desert where the general direction of flow in the alluvial aquifer is south and even a little to the southeast. The conclusion that spring discharge in Death Valley involves primarily carbonate-derived groundwater is supported by geochemical investigations performed by the University of Nevada, Las Vegas (DIRS 181435-Koonce et al. 2006, all). Conclusions of this study suggest there could be a contribution of volcanic aquifer groundwater from areas to the north of Ash Meadows and north of Amargosa Desert in these Death Valley discharges. In terms of groundwater flow from beneath the area of Yucca Mountain, this conclusion appears to substantiate the basis for the name of the Alkali Flat-Furnace Creek groundwater basin. That is, the predominant flow in the basin might contribute to the discharges in the Furnace Creek area of Death Valley. However, water that moves south from the volcanic aquifers (such as from the Yucca Mountain area) is not a primary source for those discharges.

Use

The Yucca Mountain FEIS discussed the concept of *hydrographic areas*, which the State of Nevada uses as basic map units in its water planning and appropriation efforts, and which often have slightly different boundaries than the sections shown in Figure 3-8. Figure 3-9 shows the hydrographic areas in the general area of Yucca Mountain. The Yucca Mountain FEIS characterized use of water from the Fortymile Canyon-Jackass Flats hydrographic area (Area 227A) for the Yucca Mountain Project and the Nevada Test Site, but identified the highest water use in the nearby region as in the Amargosa Desert hydrographic area (Area 230) immediately to the south of Area 227A (Figure 3-9). Table 3-11 of the FEIS summarized pertinent information on the hydrographic areas in the immediate area of Yucca Mountain, including estimates of annual groundwater withdrawals from each hydrographic area (DIRS 155970-DOE 2002, p. 3-48). Table 3-4 updates this information. Water withdrawal quantities, with the exception of those for Oasis Valley, are the annual averages from 2000 to 2004, which are the last 5 years of available record as published by the U.S. Geological Survey. The withdrawals for Jackass Flats, Crater Flat, and Amargosa Desert each show a slight decrease from those in the Yucca Mountain FEIS. The decrease for Jackass Flats can be attributed to a decrease in characterization activities at Yucca Mountain. The largest amount of water withdrawal continues to be in the Amargosa Desert, where the annual volume is about 16 million cubic meters (13,000 acre-feet). As listed in Table 3-4, water appropriations in the Amargosa Desert continue to be higher than the amount of water actually withdrawn.

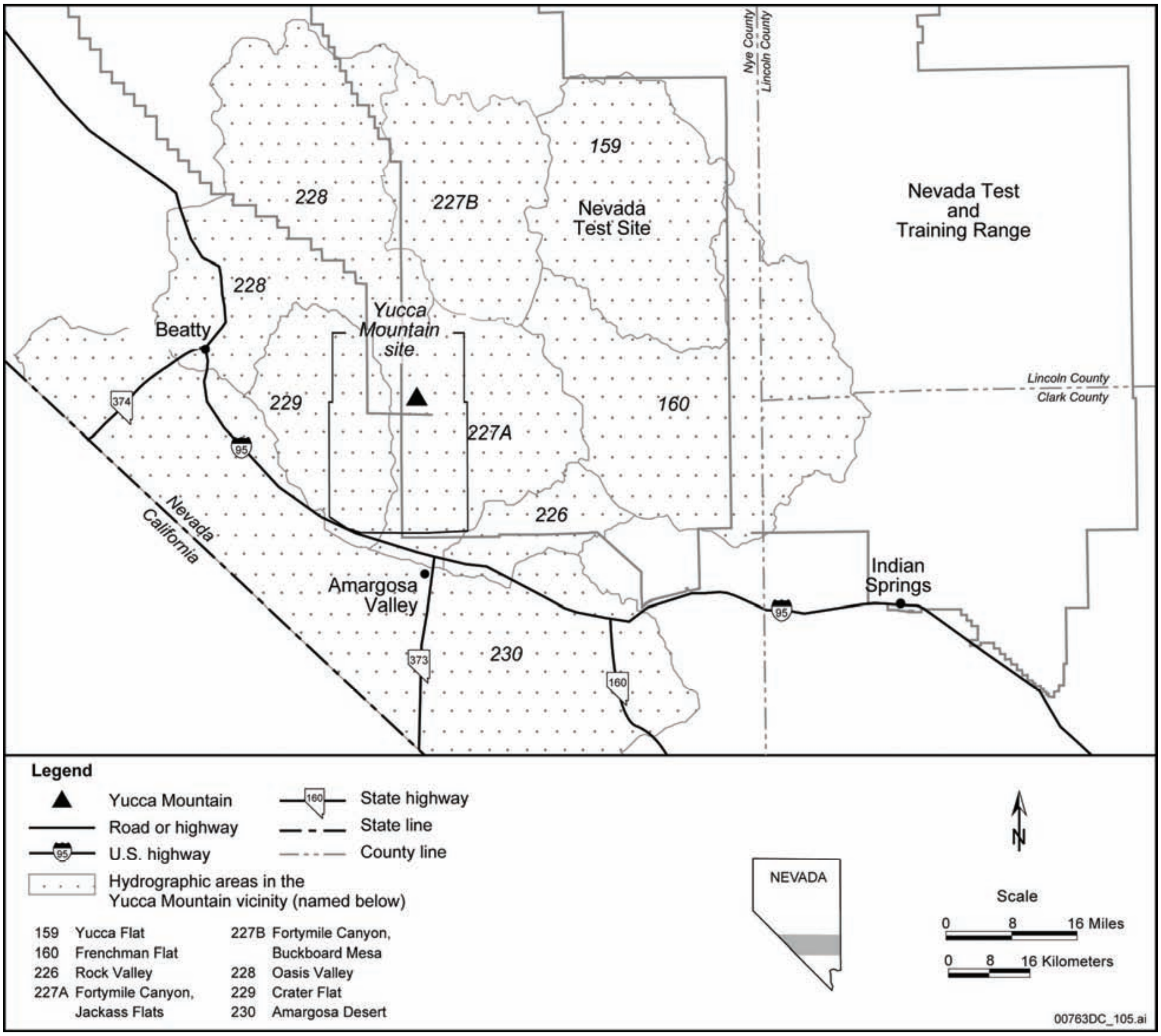


Figure 3-9. Hydrographic areas in the Yucca Mountain region.

The Yucca Mountain FEIS described the U.S. Supreme Court decision (DIRS 148102-Cappaert v. United States et al. 1976, all) in 1976 to restrict groundwater withdrawal in the Ash Meadows area to protect the water level in Devils Hole and the endangered Devils Hole pupfish. Ash Meadows is in the Amargosa Desert hydrographic area. Although Table 3-4 shows total combined groundwater withdrawals from the Amargosa Desert, the U.S. Geological Survey tracks withdrawals in the Ash Meadows area separately from those in other parts of the Amargosa Desert. Withdrawals from Ash Meadows are a very small portion (less than 1 percent) of the total withdrawals.

Regional Groundwater Quality

The Yucca Mountain FEIS described the results from a 1997 survey of several wells and springs in the Yucca Mountain region to assess the quality of the regional groundwater. Samples were collected from five groundwater sources in the Amargosa Desert, which consisted of three wells and two springs, and from three wells in the immediate vicinity of Yucca Mountain. Table 3-12 of the FEIS summarized the results from this sampling effort and compared them with EPA drinking water standards (DIRS 155970-

Table 3-4. Perennial yield and water use in the Yucca Mountain region.

Hydrographic area[a]	Perennial yield[b,c,d] (acre-feet per year)[e]	Current appropriations/ committed resources[f,g] (acre-feet per year)	Average annual withdrawals, 2000 to 2004, unless noted otherwise (acre-feet)	Chief uses
Jackass Flats (Area 227A)	880[h] – 4,000	58[i]	89[j,k]	Nevada Test Site programs and minor amounts for the Yucca Mountain Project
Crater Flat (Area 229)	220 – 1,000	1,100	63[j]	Mining, amounts for the Yucca Mountain Project
Amargosa Desert (Area 230)	24,000 – 34,000	25,000	13,000[j]	Irrigation, mining, livestock, quasi-municipal or commercial, and domestic
Oasis Valley (Area 228)	1,000 – 2,000	1,300	130 (for 2000)[g]	Irrigation and municipal

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. A specific area in which the State of Nevada allocates and manages the groundwater resources.

b. The quantity of groundwater that can be withdrawn annually from a groundwater reservoir, or basin, for an indefinite period without depleting the reservoir; also referred to as safe yield.

c. Source: DIRS 147766-Thiel 1999, pp. 8 and 10 to 12.

d. In many of its planning documents, the Nevada Division of Water Resources identifies a combined perennial yield of 24,000 acre-feet for Hydrographic Areas 225 through 230.

e. An acre-foot is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot.

f. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations are for underground rights only, and do not cover Federal Reserve Water Rights held by the Nevada Test Site or U.S. Air Force. This latter exclusion is the reason withdrawals from Area 227A are shown as exceeding the identified appropriations (that is, the Nevada Test Site withdrew water under its Federal Reserve Water Rights).

g. Source (except for Crater Flat): DIRS 176600-Converse Consultants 2005, pp. 98 and 99 for committed resources, p. 37 for annual withdrawal from Oasis Valley.
Source (for Crater Flat): DIRS 178726-State of Nevada 2006, all.

h. The low estimate for perennial yield from Jackass Flats breaks the quantity down into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds. The Yucca Mountain Project production wells are in the western portion of this hydrographic area.

i. Based on the southern boundary of Area 227A, as defined in a 1979 Designation Order by the State Engineer, there should be only 17 acre-feet of committed resources in Area 227A. However, water-rights information from the Nevada Division of Water Resources shows 58 acre-feet in committed resources for this area. The apparent discrepancy appears to be the result of 41 acre-feet of committed resources (including one certificate for domestic use and one for commercial use) being inside the pre-1979 boundary and outside the post-1979 boundary. Both certifications are for wells near U.S. Highway 95. The remaining 17 acre-feet of committed resources (which appear to be in Area 227A) are attributed to two certificates the Bureau of Land Management owns for stock watering wells.

j. Sources: DIRS 178692-La Camera et al. 2005, pp. 72 and 73 for water withdrawals from 2000 to 2003; DIRS 178691-La Camera et al. 2006, p. 69 for water withdrawals in 2004. (Includes only Nevada Test Site water use in Area 227A.)

k. Sources include only Nevada Test Site water use from Area 227A. The sources for the Yucca Mountain Project water use from Area 227A (about 21 acre-feet per year) are DIRS 181575-Wade 2000, all; DIRS 181576-Wade 2000, all; DIRS 181577-Wade 2000, all; DIRS 181578-Wade 2001, all; DIRS 181580-Wade 2002, all; DIRS 181581-Wade 2003, all; DIRS 181582-Wade 2004, all; and DIRS 181583-Wade 2005, all.

DOE 2002, p.3-49), with the recognition that these standards are for public water supply systems, not for potential water sources for such systems. The evaluation concluded that the overall quality of the regional groundwater is good and that the tested groundwater sources in the Amargosa Desert area met primary drinking-water standards. However, a few sources exceeded secondary and proposed standards.

Specifically, four Amargosa Desert sources exceeded a proposed standard for radon; one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Since the completion of the Yucca Mountain FEIS, the proposed standard for natural uranium has gone into effect but the proposed standard for radon is still pending. The standard for uranium is 0.03 milligram per liter [40 CFR 141.66(e)], which is slightly higher than the proposed standard considered in the FEIS. The single Amargosa Desert source that exceeded the proposed standard for uranium with a reported concentration of 0.02 milligram per liter would meet the new standard. Section 3.1.4.2.2 of this Repository SEIS addresses the radon and uranium results and the associated standards further in the discussion of water quality at Yucca Mountain. In addition, since the completion of the Yucca Mountain FEIS, the primary drinking-water standard for arsenic was lowered from 0.05 milligram per liter to 0.01 milligram per liter (40 CFR 141.23). The five samples from the Amargosa Desert area had arsenic levels that ranged from 0.01 to 0.022 milligram per liter (DIRS 104828-Covay 1997, all), so only the single source with an arsenic level of 0.01 milligram per liter would meet the current standard.

3.1.4.2.2 *Groundwater at Yucca Mountain*

This section summarizes the characteristics of groundwater at Yucca Mountain in both the unsaturated zone and the saturated zone.

Unsaturated Zone

Water Occurrence. The Yucca Mountain FEIS stated that the occurrence of water in the *unsaturated zone* at Yucca Mountain extended from the crest of the mountain approximately 750 meters (2,500 feet) down to the top of the water table. In this zone, DOE has found water in the rock matrix, along faults and other *fractures*, and in isolated pockets of saturated rock termed *perched water*. DOE provided the conceptual model shown in Figure 3-10 with the discussion of the movement and presence of water in the unsaturated zone. Although the conceptual model shows water moving throughout the unsaturated zone, the representation shows the pathways, not the amount of water. At the time of FEIS completion, DOE had excavated more than 10.6 kilometers (6.6 miles) of tunnels and testing *alcoves* in Yucca Mountain and found no active flow of water; the Department observed only one fracture in the rock to be moist. Since the completion of the FEIS, DOE has observed and documented a seepage event, which occurred in February 2005 in the South Ramp of the Exploratory Studies Facility after a period of extremely high precipitation in the area. The recorded precipitation from October 2004 through February 2005, at 32.5 centimeters (12.8 inches), was roughly 3.5 times the average for the preceding 9 years (1995 to 2004) for the months of October though February (DIRS 177754-Finsterle and Seol 2006, p.1). The seepage or dripping occurred in strata of the Tiva Canyon welded unit, above the Paintbrush nonwelded unit (Figure 3-10). The Paintbrush nonwelded unit acts to slow the downward movement of water and the Tiva Canyon welded unit is likely to exhibit relatively fast flow. No seepage was observed in the proposed repository area, located in the Topopah Spring welded unit below the Paintbrush nonwelded unit. An evaluation in May 2006 (DIRS 177754-Finsterle and Seol 2006, all) verified that the seepage event was consistent with conceptual models of the site. The evaluation minimally adapted the modeling approach used to estimate long-term ambient seepage into emplacement areas of the repository to estimate short-term seepage into the South Ramp. It found that the model and approach developed for the long-term performance of the repository estimated seepage in the South Ramp area reasonably consistent with observations in February 2005 (DIRS 177754-Finsterle and Seol 2006, p. 17). DOE reported the detection of the seepage to the U.S. Nuclear Regulatory Commission (NRC) (DIRS 173954-Ziegler 2005, all), but did not identify it as a “Technically Significant Condition” because DOE’s conceptual models of the site predicted this type of seepage under high-precipitation conditions.

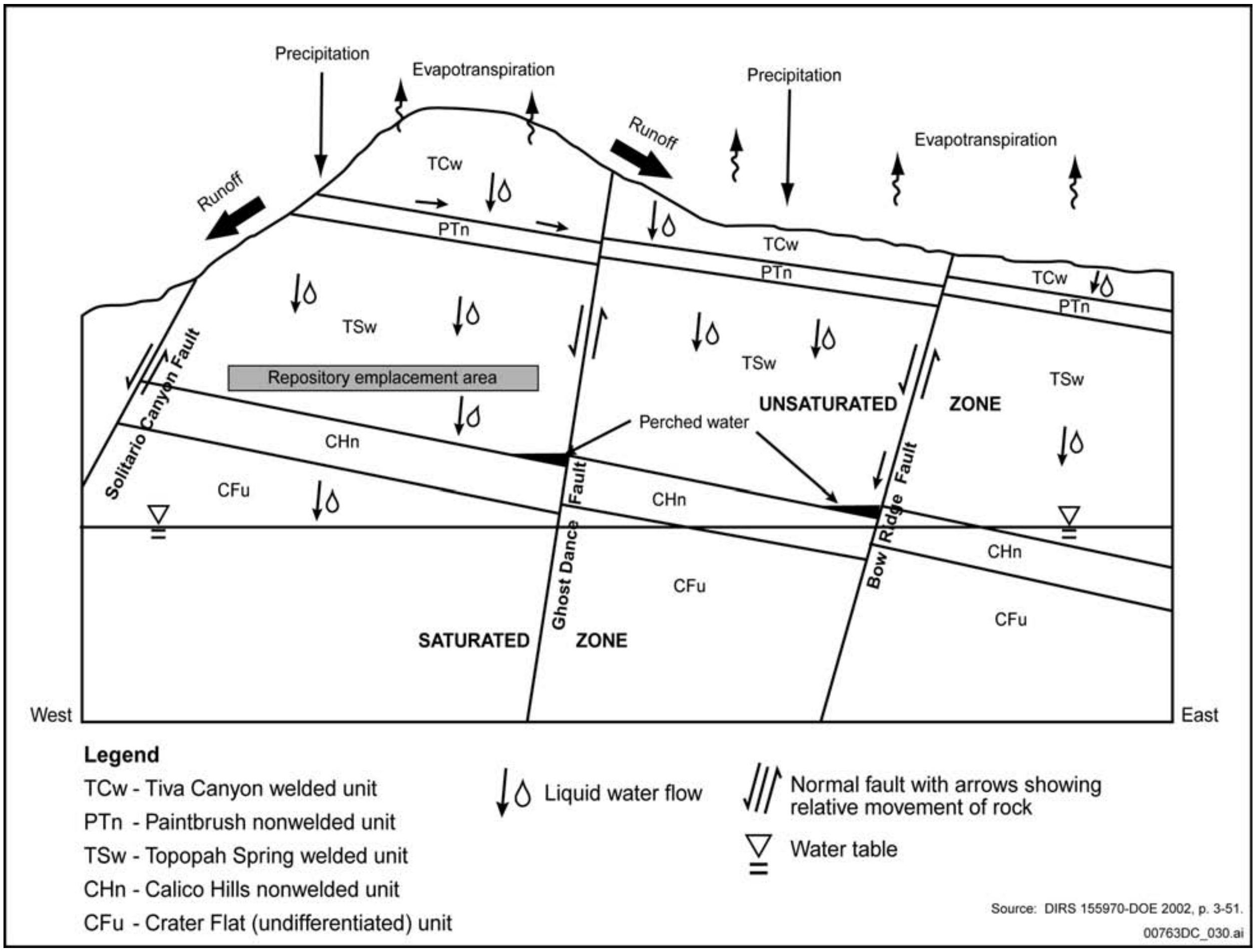


Figure 3-10. Conceptual model of water flow at Yucca Mountain.

DOE's investigations of the unsaturated zone at Yucca Mountain found that water in the pores of rock is older and chemically distinct from water in fractures and in the perched water bodies. Water that moves along fractures probably is responsible for recharge of the perched water where the moving water encounters less-*permeable* rock and fault fill materials. As shown in Figure 3-10, perched water bodies occur near the base of the Topopah Spring welded unit, about 100 to 200 meters (330 to 660 feet) below the proposed repository horizon. To help characterize the nature of water movement in the unsaturated zone, DOE has performed carbon dating on samples of perched water and found apparent ages, or residence times, of 3,500 to 11,000 years. Because there are limitations on the use of carbon dating in this type of circumstance, DOE also looked for the presence of tritium in the perched water, which would indicate contributions from water after 1952 when it would have been affected by atmospheric nuclear weapons testing. The results indicated that tritium levels, if present, were too small for reliable detection.

Hydrologic Properties of Rock. The Yucca Mountain FEIS described the layers of rock and deposited materials at Yucca Mountain and the areas immediately surrounding it. The FEIS presented the layers, from the top down, in terms of stratigraphic units, which are defined by geologic properties of the rock, and hydrogeologic units, which reflect the manner in which water moves through the rock. In general, the origin of the rock and the manner of its deposition determine the stratigraphic units. Changes in these characteristics often coincide with changes in how water moves, so stratigraphic and hydrogeologic units might start or stop at the same observed physical change in the rock strata. In other instances, however, they might not coincide. For example, deposition of a sequence of volcanic rock might have occurred through one continuous event that formed a single stratigraphic unit, but if the upper portions of the sequence were more fractured, enhancing the potential for water movement, it would probably be designated as a separate hydrogeologic unit from the lower portion of the sequence. Figure 3-17 of the Yucca Mountain FEIS showed the strata, or layers, that DOE mapped through subsurface investigations in the Yucca Mountain vicinity (DIRS 155970-DOE 2002, p. 3-52). The layers are in terms of the stratigraphic units discussed in the geology sections of the affected environment and the hydrogeologic units that provide the basis for hydrology discussions. Table 3-13 of the FEIS listed the specific hydrogeologic units in the unsaturated zone at Yucca Mountain (DIRS 155970-DOE 2002, p. 3-53). Both provided descriptive characteristics of the identified rock layers.

Water Source and Movement. Precipitation at Yucca Mountain runs off, evaporates, or infiltrates into the ground where it is subject to later evaporation or *transpiration* by vegetation. Some of the water infiltrates deeply enough to be out of the influence of surface effects and can continue to move downward if conditions support such movement. DOE efforts since the completion of the Yucca Mountain FEIS have included development of a new model of net infiltration for the Yucca Mountain site (DIRS 174294-SNL 2007, all). According to this model, net infiltration under the current climate averages 14.3 millimeters (0.56 inch) per year over the study area of 125 square kilometers (30,900 acres), roughly centered over the Yucca Mountain site, and 17.6 millimeters (0.69 inch) per year over the repository footprint (DIRS 174294-SNL 2007, p. 6-170). Over smaller areas, the model shows wide variations in infiltration due to physical parameters such as soil, bedrock, vegetation, and the amount of lateral runoff. Soil depth is one of the most significant factors in estimates of local infiltration. The model estimates that areas of shallow [with average depths of 0.4 meter (1.3 feet)] or no soil comprise about 58 percent of the land area within the 125-square-kilometer study area, but account for almost 97 percent of the total infiltration (DIRS 174294-SNL 2007, p. 6-82 and p. 6-195). To assess the long-term performance of the proposed repository, the infiltration model includes estimates of infiltration during a monsoon climate and a cooler and wetter glacial-transition climate. These are the three climates (present-day, monsoon, and glacial-transition) DOE has predicted and modeled to occur up to 10,000 years into the future for the Yucca Mountain area (DIRS 174294-SNL 2007, p. 1-1). Both the monsoon and glacial-transition climates involve predicted net infiltration rates that are higher than those for the present-day climate (DIRS 174294-SNL 2007, p. 6-203).

Once through surface alluvium, water in the unsaturated zone at Yucca Mountain moves either very slowly through pore spaces in the rock or relatively rapidly through faults and fractures. Flow through faults and fractures probably occurs in episodic events that correspond to periods of high surface infiltration and, as noted above, is the likely source of the isolated perched water bodies under the zone where DOE would construct the proposed repository. The nature of this downward movement depends on the hydrogeologic properties of the rock layers. The Tiva Canyon welded unit (Figure 3-10) at the top of the rock sequence (and below the alluvium in many areas) at Yucca Mountain supports fairly rapid water transport through factures, but the underlying Paintbrush nonwelded unit has high porosity and low fracture density and tends to slow the water. DOE studies described in the Yucca Mountain FEIS investigated the presence of the naturally occurring radioactive isotope chlorine-36 in the Exploratory Studies Facility. Those studies suggested that some isolated pathways in the Paintbrush nonwelded unit allow small amounts of water to reach the underlying Topopah Spring welded unit fairly rapidly. The repository would be in the Topopah Spring welded unit, which has extensive fracturing that allows relatively rapid water movement. At the base of the Topopah Spring welded unit, water encounters low-

permeability zones that include the top of the Calico Hills nonwelded unit. All of these rock layers, or hydrogeologic units, dip (slant) as shown in Figure 3-10, so water will continue to move downward, but laterally, over the top of the low-permeability zone until it reaches a vertical pathway, such as a fault. Perched water bodies can form when the water encounters less permeable rock and fault-gouge material that block it from reaching a fault such that lateral and vertical movement is blocked and the water accumulates. As shown in Figure 3-10, water moving through the Calico Hills nonwelded unit (or past the unit through fault zones) encounters the Crater Flat unit and the water table.

Although the preceding discussion included terms such as “slow” and “rapid” in the description of water movement in the unsaturated zone at Yucca Mountain, it describes water movement in one hydrogeologic unit in comparison with another, so movement speed is relative. DOE has developed models of groundwater movement in the unsaturated zone and has run a model that applied the most realistic parameters, rather than parameters that tend to be conservative. The results indicate that it would take 7,000 to 8,000 years for 50 percent of a hypothetical, nonabsorbing tracer that infiltrated the surface at Yucca Mountain to travel approximately 750 meters (2,500 feet) vertically to the underlying water table (DIRS 156609-BSC 2001, p. 183). Some of the tracer would find its way to the water table faster, and some would take more than 8,000 years to reach the water table.

The Yucca Mountain FEIS described chlorine-36 studies in detail because the results suggested that infiltrating water pathways of 50 years or less could exist from the surface to the subsurface level of the proposed repository. Because of the significance of these results and the complexities and uncertainties of the analyses, DOE initiated additional studies to determine if independent laboratories and related isotopic studies could corroborate the findings. Since the completion of the Yucca Mountain FEIS, DOE and the U.S. Geological Survey completed a significant element of these studies in the form of a validation study (DIRS 179489-BSC 2006, all). The U.S. Geological Survey designed the study to include investigations for chlorine-36 and tritium (another radioactive isotope). In addition to the U.S. Geological Survey, study participants included two DOE national laboratories. The validation study resulted in mixed findings. One study participant ran the analyses, but the results did not show evidence of chlorine-36-to-total-chlorine ratios that would indicate the presence of recent bomb-pulse water. Another participant reproduced the results from the earlier studies that the Yucca Mountain FEIS discussed. The concurrent tritium studies concluded that water extracted from rock in areas of known faulting indicated the presence of modern water (water that entered the unsaturated zone after 1952) (DIRS 179489-BSC 2006, pp. v and vi). The report of the validity study includes recommendations to improve the study and to better understand the results obtained (DIRS 179489-BSC 2006, pp. 59 and 60). These findings, although inconsistent and inconclusive, have not precluded the presence of relatively fast pathways for small amounts of water in some subsurface locations.

Unsaturated Zone Groundwater Quality. The Yucca Mountain FEIS compared the water chemistry of pore water and perched water collected at Yucca Mountain. The pore water was higher in dissolved minerals than the perched water, particularly chloride, which indicates that perched water had little interaction with rock. This, in turn, provided strong evidence that flow through faults and fractures is the primary source of perched water.

Saturated Zone

Water Occurrence. The Yucca Mountain FEIS described the aquifers and confining units in the *saturated zone* at Yucca Mountain. It indicated that the upper and lower volcanic aquifers consisted primarily of the Topopah Spring Tuff and the lower tuffs of the Crater Flat Group, respectively. As shown in Figure 3-10, the upper Topopah Spring Tuff (or the equivalent hydrogeologic unit, the Topopah Spring welded unit) in which the upper volcanic aquifer occurs, is above the water table in the area of the proposed repository and below the water table to the east and south of the repository footprint. Further south of the Yucca Mountain site and downgradient in the groundwater flow path, the volcanic aquifers gradually transition or, as the recent Nye County investigations indicate, abruptly end when they reach a fault and groundwater movement continues in the alluvial aquifer into the valley-fill materials of the Amargosa Desert. Underlying the volcanic and alluvial aquifers is the lower carbonate aquifer (generally referred to as the carbonate aquifer in this document), as shown in the highly stylized and simplified cross section of Figure 3-11. The carbonate aquifer, which is more than 1,250 meters (4,100 feet) below the proposed repository horizon, consists of Paleozoic carbonate rocks (limestone and dolomite) that were extensively fractured during many periods of mountain building. Studies indicate that this deep aquifer represents a regionally extensive system, though fragmented, that can transmit large amounts of groundwater when compartments are hydraulically connected.

Data from the few wells that penetrate the lower carbonate aquifer indicate that it has an upward gradient; that is, on well penetration, water rises in the well to an elevation above the aquifer. This occurred at a deep well near Yucca Mountain where the water level, or potentiometric head, of the carbonate aquifer was about 20 meters (66 feet) higher than the water level in the overlying volcanic aquifer. It also occurred in a well drilled for the Nye County program about 19 kilometers (12 miles) south of the repository site where the water rose 8 meters (26 feet) higher than the water in the overlying volcanic aquifer. Several other wells near Yucca Mountain that extend as deep as the confining unit at the base of the lower volcanic aquifer show higher potentiometric levels in that unit than in the overlying volcanic aquifers. This might be another indication of an upward hydraulic gradient in the carbonate aquifer. The upward hydraulic gradient in the carbonate aquifer is important because it prevents water in the overlying volcanic aquifers from moving downward. This is significant in the assessment of the postclosure performance of the proposed repository (see Chapter 5 of this Repository SEIS) because it constrains the pathway by which *radionuclides* could move after repository closure.

DOE has studied mineralogical data, isotopic data, and natural features at Yucca Mountain, as well as evidence of climate changes over the past few hundred thousand years, to evaluate how groundwater levels changed in the past and how they might change in the future. These studies concluded that during the Quaternary Period (that is, the last 1.6 million years), the regional water table might have been more than 100 meters (330 feet) above the present level beneath Yucca Mountain. Based on these studies and under a hypothetical wetter climate in the future, DOE believes the water table could rise by an estimated 60 to 150 meters (200 to 490 feet) (DIRS 169734-BSC 2004, pp. 8-105 and 8-106). The repository horizon would be well above these historic and future maximum water table elevations.

The Yucca Mountain FEIS discussed opposing views on the historical water level at Yucca Mountain and on the level to which the water could rise in the future. One of the opposing views suggested that deposits of calcium carbonate and opaline silica in some rock fractures at Yucca Mountain could have been deposited by hydrothermal fluids from below that were driven upward by earthquakes or hydrothermal processes that could occur in the future. Another opposing view, presented several years later, looked at the presence of the carbonate-opal veinlets at Yucca Mountain and concluded that the water inclusions in the deposits were formed at elevated temperatures, which supported the conclusion they were formed by warm upwelling water rather than by precipitation moving downward.

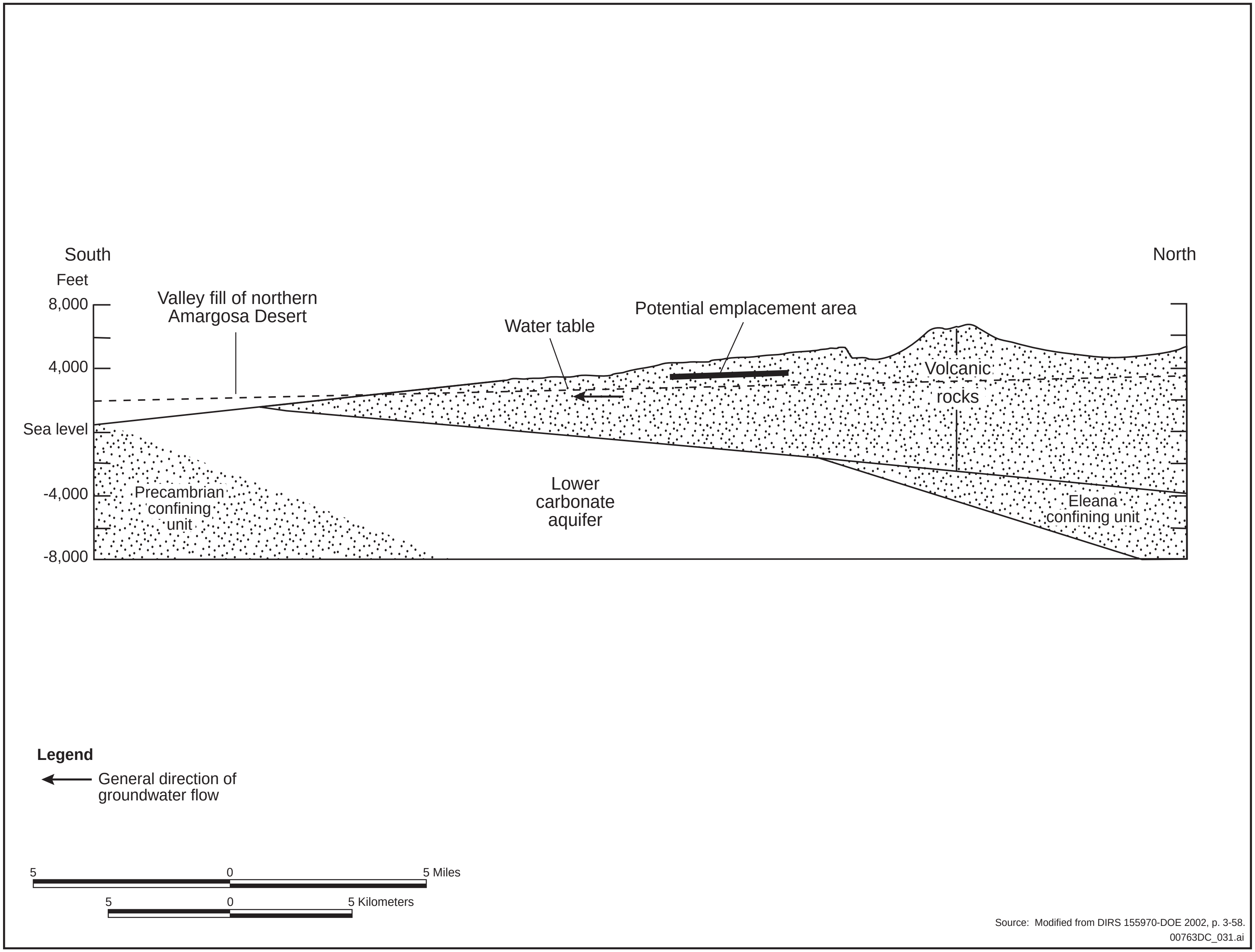


Figure 3-11. Cross section from northern Yucca Mountain to northern Amargosa Desert, showing generalized geology and the water table.

In 1990, DOE convened a panel of experts that included members of the National Academy of Sciences to review the evidence of the first opposing view. The panel concluded that the mechanism suggested for causing water upwelling could not raise the water table more than a few tens of meters and that the carbonate-rich deposits in rock fractures were from surface-down processes (precipitation) rather than the opposite. In 1998, a second group of independent experts, including U.S. Geological Survey and university representatives, reviewed the second theory of warm upwelling. The group of independent experts disagreed with some of the central scientific conclusions put forth by the second opposing view. In this case, as reported in the Yucca Mountain FEIS, both parties agreed that additional research was necessary to resolve the issue; DOE supported an independent investigation by the University of Nevada, Las Vegas, and invited the U.S. Geological Survey and the State of Nevada to participate.

Since the completion of the Yucca Mountain FEIS, the University of Nevada, Las Vegas reported on the results of its study (DIRS 182120-Wilson and Cline 2002, all; DIRS 182121-Wilson et al. 2002, all; DIRS 163589-Wilson et al. 2003, all). The study looked at 155 samples from tunnels in the Exploratory Studies Facility at Yucca Mountain and considered several different means to investigate how the carbonate-opal veinlets were deposited. It included the analysis of secondary mineral deposits and the isotope signatures of those deposits. It also included use of uranium-lead techniques to date the silica minerals associated with fluid inclusions. The researchers believed that the results supported a detailed time-temperature history of fluid migration through rock pores at Yucca Mountain during the past 8 to 9 million years (DIRS 182121-Wilson et al. 2002, p. 4). The conclusion of the study was that carbonate-opal veinlets were the result of descending meteoric water (i.e., water infiltrating from above), not from the upwelling of hydrothermal fluids (DIRS 182120-Wilson and Cline 2002, p. 25; DIRS 182121-Wilson et al. 2002, p. 26).

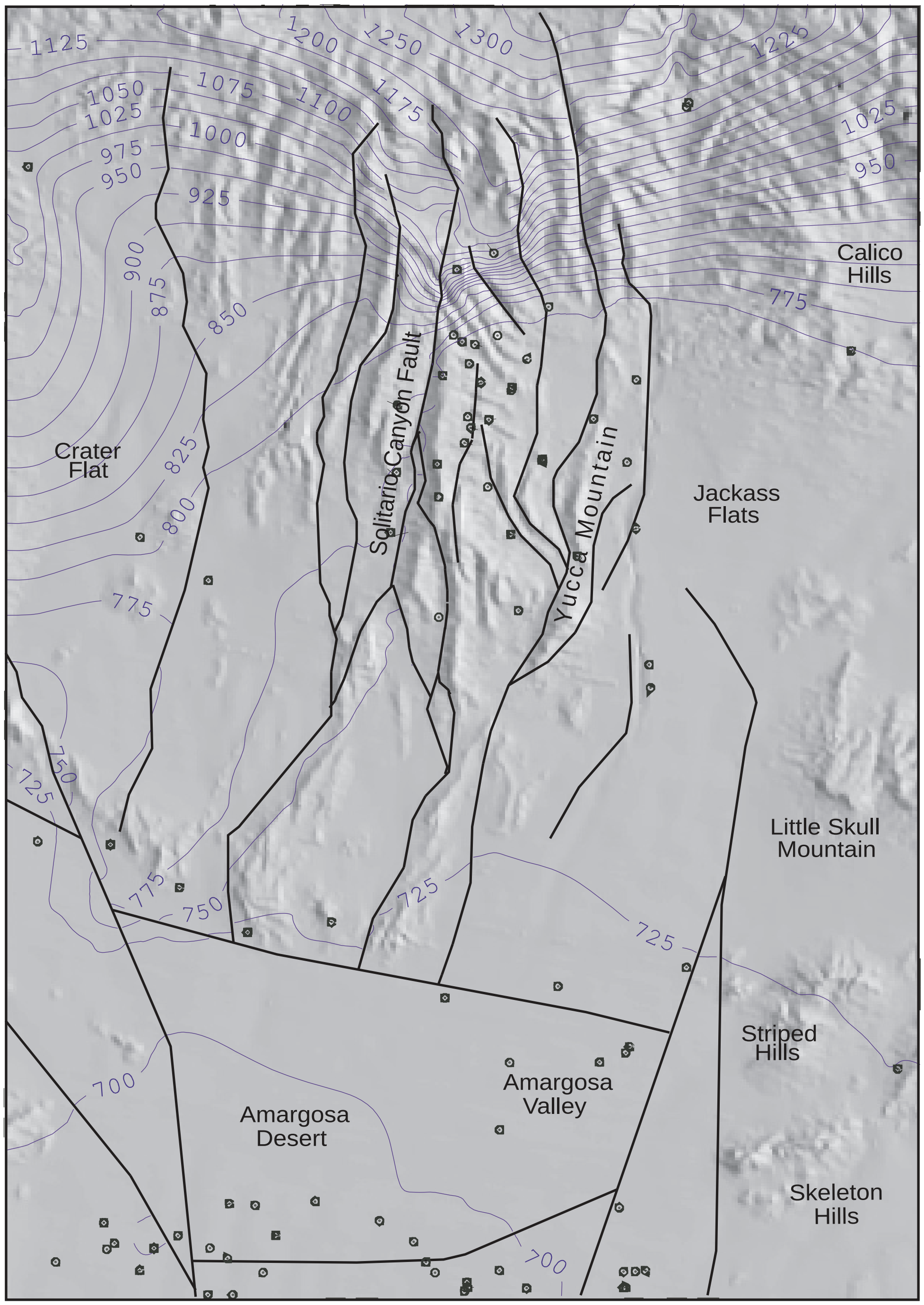
An October 2003 letter (DIRS 181056-Swainston 2003, all) sent to the Nuclear Waste Technical Review Board by a lawyer who represented proponents of the upwelling fluids scenario included a review of the University of Nevada, Las Vegas report (DIRS 182120-Wilson and Cline 2002, all; DIRS 182121-Wilson et al. 2002, all). According to the letter, the scientists who proposed the opposing view disagreed with the conclusions in the University report and "are convinced, based on many lines of evidence, that the secondary minerals were deposited by hydrothermal fluids driven from deep beneath Yucca Mountain and that episodes of such deposition are recent in geologic time." A February 2004 letter of response from the Nuclear Waste Technical Review Board (DIRS 181239-Parizek 2004, all) indicated that the information provided "would not alter the Board's previous conclusion that the evidence presented does not make a credible case for the hypothesis of ongoing, intermittent hydrothermal activity at Yucca Mountain," but recognized that differences of opinion might still exist.

Hydrologic Properties of Rock. The Yucca Mountain FEIS provided definitions for the hydrologic properties of transmissivity, conductivity, and porosity and, in Table 3-15, listed typical values or ranges of values for the three aquifers and two interlying confining units at Yucca Mountain (DIRS 155970-DOE 2002, p. 3-62). The discussion presented some considerations in the interpretation or understanding of the values in the table. This included findings at Yucca Mountain that showed rock with the highest porosity often had low transmissivity. This is attributable to a condition in which the rock contains many voids that result in high porosity, but the voids are not interconnected and the rock is in an area of low fracturing. With low amounts of interconnected void spaces and few fracture seams, water pathways are limited and the transmissivity is low. Other factors to consider in understanding the values include the limited number of tests performed on the carbonate aquifer due to the limited number of wells that reach that depth and the ability to only measure apparent values from single boreholes; that is, the measured values are representative of a small area around the borehole, and might change significantly in the immediate area if water-bearing fractures are in the tested well zone.

Water Source and Movement. As reported in the Yucca Mountain FEIS, DOE has studied groundwater levels at Yucca Mountain for years and found them to be very stable. Excluding changes due to pumping, the observed fluctuations in groundwater level were attributed to natural phenomena such as barometric pressure changes and Earth tides; short-term fluctuations have been linked to apparent recharge events and earthquakes.

Hydrologists typically generate maps that show the elevation of the groundwater surface, also called the potentiometric surface, with contour lines of equal elevation. Lines perpendicular to the contour lines represent the direction of slope of the groundwater surface, which is the implied direction of groundwater flow. At Yucca Mountain, the potentiometric surface consists of three zones. On the west side of the mountain, the potentiometric surface slopes moderately to the southeast, dropping in elevation about 20 to 40 meters (66 to 130 feet) in 1 kilometer (0.6 mile). The east boundary of this zone is the Solitario Canyon fault on the west side of Yucca Mountain. The fault zone apparently impedes flow and on its east side is the second zone where the water surface has a very gentle slope, dropping only 0.1 to 0.4 meter per kilometer (0.33 to 1.3 feet per mile). This zone of gentle slope underlies Yucca Mountain. The southeast direction of the slope is a local condition in the regional southward groundwater flow. The third zone is an area of steep slope in the potentiometric surface north of Yucca Mountain. In this zone, the groundwater appears to drop sharply toward the south; about 110 meters vertically over a horizontal distance of 1 kilometer (about 360 feet per mile), which generates a hydraulic gradient of 0.11 (DIRS 170009-BSC 2004, p. 6-20). The Yucca Mountain FEIS described possible reasons for this steep slope, but concluded that there were no obvious geologic reasons and that it was still under investigation. Figure 3-12 shows the potentiometric surface contours for the area of Yucca Mountain, which are consistent with the preceding discussion and which this discussion refers to as the Version A contours.

Since the completion of the Yucca Mountain FEIS, DOE investigations of this steep hydraulic gradient have continued, but the efforts have not reached an unequivocal explanation (DIRS 170009-BSC 2004, p. 6-21). DOE based the predictions of the groundwater elevation contours in the area of the steep gradient, to a large extent, on measured groundwater elevations in three different boreholes north of Yucca Mountain. These three boreholes (UE-25 WT 6, USW G-2, and USW WT-24) are within a circle about 1.6 kilometers (1 mile) in diameter (DIRS 170009-BSC 2004, p. 1-3). Two of the boreholes have measured water elevations notably higher than the one farthest to the south (USW WT-24). The Yucca Mountain FEIS identified a possible reason for the steep hydraulic gradient—that water in at least some of the boreholes in this area is perched water and not part of the regional water table. In pursuing this possibility, DOE has regenerated the potentiometric surface map (Version B) of the Yucca Mountain vicinity with the assumption that water in boreholes UE-25 WT 6 and USW G-2 is perched water (DIRS 170009-BSC 2004, p. 6-17); that is, of the three boreholes in the area immediately north of Yucca Mountain, DOE used only the water elevation measured in USW WT-24 along with other area data points in the development of the revised contours in this area. Version B (Figure 3-13) shows that, without the use of data from the two boreholes, the elevation contours at the north portion of Yucca Mountain have smoother curves and are slightly further apart than those in Figure 3-12. As a result of the wider spaced contour lines, the hydraulic gradient in the area of the steep zone declines to 0.06 to 0.07. Possibly of more significance, DOE evaluated both the perched and nonperched scenarios in its groundwater model and found them to yield similar flow characteristics. This supports earlier findings of an expert panel that concluded that, whether the steep slope was due to perched water or not, it would have no effect on



Universal Transverse Mercator projection, Zone 11.
Shaded-relief base from 1:250,000-scale Digital Elevation Model;
sun illumination from northeast at 30 degrees above horizon

Legend

—700— Potentiometric contour shows altitude of potentiometric surface in meters. Datum is sea level.

Tertiary fault

Well locations from which groundwater elevations were obtained for those dots.

0 2 4 Miles

0 2 4 6 Kilometers

Source: Modified from DIRS 170009-BSC 2004, p. 6-38

00763DC_115.ai

Figure 3-12. Original potentiometric surface map for the Yucca Mountain area (considering groundwater elevations in all applicable boreholes).

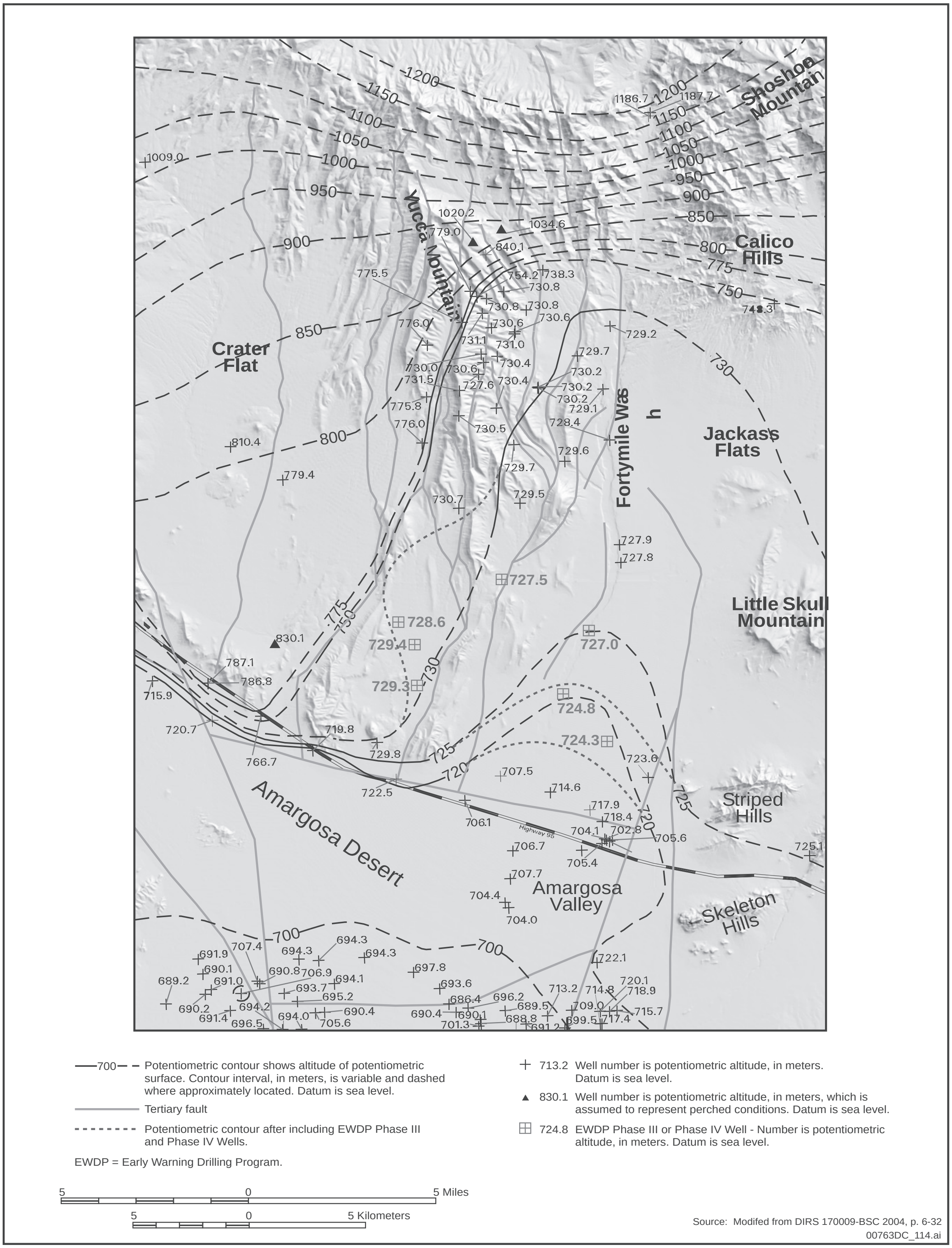


Figure 3-13. Revised potentiometric surface map for the Yucca Mountain area (excluding groundwater elevations from boreholes UE-25 WT 6 and USW G-2).

repository performance (DIRS 170009-BSC 2004, p. 6-21). The lower central portion of Figure 3-13 shows several possible changes to contours as a result of recent findings from the Nye County drilling program.

The Yucca Mountain FEIS described an opposing view to the stability of groundwater levels at Yucca Mountain that suggested earthquakes in the area could cause substantial rises of the water table, and could even flood the repository. The FEIS also described the expert panel review of the information and theory behind this view and the conclusion of the panel that a rise of groundwater to the level of the repository was essentially improbable. DOE has received no additional support for this opposing view since it completed the FEIS.

Inflow to Volcanic Aquifers at Yucca Mountain. The Yucca Mountain FEIS described the four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. DOE does not know the actual amounts of water inflow from these potential sources and cannot measure them on a large-scale basis, but it has developed estimates for incorporation into regional- and site-scale models of the unsaturated and saturated zones. According to these estimates, which are based on data collected and tests performed, the amount of inflow due to precipitation at Yucca Mountain is small in comparison with inflow from volcanic aquifers to the north, and it is less than estimates of recharge along the length of Fortymile Wash. The higher potentiometric surface of the carbonate aquifer in the area of Yucca Mountain would support inflow to the volcanic aquifer above it, but only if structural pathways existed. The amount of inflow from the carbonate aquifer, if it exists, is unknown.

Outflow from Volcanic Aquifers at and near Yucca Mountain. The Yucca Mountain FEIS described the three pathways by which water might leave the volcanic aquifers in the vicinity of Yucca Mountain as (1) downgradient movement into other volcanic and alluvial aquifers in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates this does not occur), and (3) upward movement into the unsaturated zone. The Yucca Mountain FEIS mentioned a fourth pathway, pumping of water from the aquifer. With the exception of pumping from wells, the actual amounts of water outflow along these pathways are unknown. Based on investigations of the area and the potentiometric surface of the groundwater, the pathway for groundwater beneath Yucca Mountain is southerly through volcanic aquifers before it encounters the alluvial aquifer of the Amargosa Desert.

Available data on the potentiometric head of the carbonate aquifer indicate that any movement of water between carbonate and volcanic aquifers in the area of Yucca Mountain would be upward. Upward movement of water to the unsaturated zone is the third pathway for water to leave the volcanic aquifer. However, based on collected data, DOE believes there is a net downward movement of water in the unsaturated zone.

Use. The Yucca Mountain FEIS described the historic use of groundwater in the immediate area of Yucca Mountain, which largely consisted of DOE water withdrawals. Two wells, J-12 and J-13, are in Jackass Flats (Hydrographic Area 227A) on the east side of Yucca Mountain and are the nearest production wells to the proposed repository site (DIRS 155970-DOE 2002, p. 3-65). DOE has used these wells to support water needs for Area 25 of the Nevada Test Site and the Yucca Mountain Project. The Department has pumped groundwater from other wells in the immediate area in support of Yucca Mountain characterization activities, which include wells in Crater Flat on the west side of the mountain.

For the most part, these withdrawals have been small. Exceptions were the relatively large volumes—up to 230,000 cubic meters (190 acre-feet) per year—that DOE pumped from the C-Well complex, also in Jackass Flats, as part of aquifer testing actions. Water from the C-Wells was reinjected as part of the testing. Table 3-16 of the Yucca Mountain FEIS summarized the quantities of water from J-12 and J-13 and from the C-Well complex for 1992 to 1997 and estimates for several years after 1997 (DIRS 155970-DOE 2002, p. 3-66). Since the completion of the Yucca Mountain FEIS, actual quantities of water pumped from Jackass Flats have dropped sharply. In 1997, the last year of record in Table 3-16 of the FEIS, about 420,000 cubic meters (340 acre-feet) of water were withdrawn from Jackass Flats. By 2000 and 2001, that number dropped to less than half the 1997 value to about 170,000 cubic meters (140 acre-feet) per year (DIRS 178692-La Camera et al. 2005, pp. 72 and 73; DIRS 181575-Wade 2000, all; DIRS 181576-Wade 2000, all; DIRS 181577-Wade 2000, all; DIRS 181578-Wade 2001, all; and DIRS 181580-Wade 2002, all). From 2002 to 2004, withdrawals dropped further, ranging from about 57,000 to 83,000 cubic meters (46 to 67 acre-feet) per year (DIRS 178692-La Camera et al. 2005, pp. 72 and 73; DIRS 178691-La Camera et al. 2006, p. 69; DIRS 181581-Wade 2003, all; DIRS 181582-Wade 2004, all; and DIRS 181583-Wade 2005, all). The large reductions in groundwater use are attributable to the reduction in water needs at the Yucca Mountain site as characterization activities ended and the project moved into licensing activities. Current water use at the site is only about 6,000 cubic meters (5 acre-feet) of water per year. (As noted above, the remaining groundwater withdrawals from Jackass Flats are attributable to Nevada Test Site needs.)

Table 3-17 of the Yucca Mountain FEIS summarized the results of long-term efforts by the U.S. Geological Survey to monitor changes in groundwater elevations in the vicinity of Yucca Mountain (DIRS 155970-DOE 2002, p. 3-67). The table listed water-level conditions in seven wells from 1992 to 1997 and compared them with median water levels in the same wells from measurements from 1985 to 1993 (DIRS 103283-La Camera et al. 1999, p. 84). Table 3-5 updates the data presented in the FEIS by including corresponding groundwater level monitoring results from 1998 through 2004. DOE used the same baseline water elevations it used on the Yucca Mountain FEIS to calculate the elevation differences. For example, the average groundwater elevation measured in well JF-1 during 2004 was 27 centimeters (11 inches) above the baseline elevation established for that well. Table 3-5 indicates a general increase in groundwater levels in all the wells beginning in 1998 to 1999. There were only a handful of instances in which the elevation in a well dropped below that reported in the previous year, so the increasing trend was relatively steady through the monitoring period from 1998 to 2004. This trend of increasing water levels probably is due either to the decrease in water use from the basin or to changes in recharge to the groundwater system (DIRS 178691-La Camera et al. 2006, p. 14), or a combination of both.

Saturated Zone Groundwater Quality. The groundwater sampling effort described in Section 3.1.4.2.1 included three groundwater wells in the vicinity of Yucca Mountain, which include production wells J-12 and J-13. As described in the Yucca Mountain FEIS, water samples from these three wells met primary drinking-water standards set at that time by the EPA for public drinking-water systems, but each well exceeded the secondary standard for fluoride and proposed primary standards for radon. Since the completion of the Yucca Mountain FEIS, the standard for radon is not yet in effect, but the EPA has lowered the primary drinking-water standard for arsenic to 0.01 milligram per liter. The reported values for the 1997 sampling of the three wells were 0.008, 0.009, and 0.011 milligrams per liter. The new standard for arsenic, effective January 23, 2006, requires treatment of arsenic to less than 0.01 milligram per liter. DOE has installed and implemented an arsenic treatment system for the Yucca Mountain drinking-water system (DIRS 179878-BSC 2006, p. 7).

Table 3-5. Differences between annual and baseline median groundwater elevations above sea level.

Baseline elevations[a]			Difference (centimeters) from baseline median												
Well	Median (meters)	Average deviation from median (centimeters)	1992 to 1997[b]						1998 to 2004[c]						
JF-1	729.23	±6	–3	0	–6	0	–6	–3	0	+6	+9	+15	+21	+24	+27
JF-2	729.11	±9	+3	0	+3	+9	0	–3	0	+12	+18	+21	NA	+15	+18
JF-2a[d]	752.43	±12	0	+6	+12	+15	+21	+27	+43	+49	+67	+70	+70	+88	+85
J-13	728.47	±6	–3	–3	–9	–6	–12	–12	–6	0	+6	+12	+12	+18	–3
J-11	732.19	±3	0	0	+3	+6	+6	+12	+12	+6	+6	+12	+9	+12	+9
J-12	727.95	±3	0	0	–3	–3	–9	–9	–9	0	+3	+6	+9	+15	+18
JF-3	727.95	±3	NA	NA	–6	–6	–9	–9	–9	–3	+3	+6	+9	+15	+15

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Source: DIRS 103283-La Camera et al. 1999, p. 84.
b. Source: DIRS 155970-DOE 2002, p. 3-67.
c. Source: DIRS 178691-La Camera et al. 2006, p. 71.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
NA = Not available.

Table 3-18 of the Yucca Mountain FEIS listed water chemistry data for groundwater in the volcanic and carbonate aquifers at Yucca Mountain (DIRS 155970-DOE 2002, p. 3-68). Water from the volcanic aquifer has a relatively dilute sodium-potassium-bicarbonate composition; water from the carbonate aquifer is quite different, with a more concentrated calcium-magnesium-bicarbonate composition. These characteristics are consistent with the different types of rock through which the water travels.

Table 3-19 of the Yucca Mountain FEIS listed radiological concentrations from sampling of groundwater in 1997 at and near Yucca Mountain (DIRS 155970-DOE 2002, p. 3-69). This sampling effort established a baseline for *radioactivity* in groundwater from the alluvial, volcanic, and carbonate aquifers. The radioactivity concentrations were below EPA *maximum contaminant levels* for public drinking-water systems, which include the value of 4 *millirem* per year set as the total body dose limit for beta- or gamma-emitting radionuclides. The discussion noted, however, that the groundwater would exceed proposed standards for radon. The information in Table 3-19 of the FEIS and the accompanying discussion are still valid and are incorporated here by reference. Table 3-19 of the FEIS listed sample results for total uranium, but indicated there was no associated drinking-water standard. Since the completion of the FEIS, EPA has established a maximum contaminant level of 30 micrograms (or 0.03 milligram) per liter for uranium in drinking water. The total uranium values in Table 3-19 of the FEIS are all below this level.

The Yucca Mountain FEIS discussed several studies on potential groundwater *contamination* from past nuclear weapons testing at the Nevada Test Site. Radionuclide migration to groundwater has been detected. In general, DOE believes that the migration of tritium, a radionuclide that is transported in solution with water moving through the area, is limited to several kilometers. Less mobile radioactive constituents (generally those that do not go into solution or do not go into solution as completely and easily as tritium) have migrated no more than about 500 meters (1,600 feet). In one case, however, there is evidence of plutonium migration from a below-groundwater test at Pahute Mesa. Monitoring results indicate plutonium has moved at least 1.3 kilometers (0.8 mile) from the source in 28 years and might be due to the movement of very small particles called colloids. Area 25 of the Nevada Test Site, the location of Yucca Mountain and the proposed repository, was not an area of nuclear detonation testing, and DOE studies of contaminant migration from Nevada Test Site activities do not indicate that any contamination has reached the groundwater beneath Yucca Mountain. However, Pahute Mesa and Buckboard Mesa, which are areas where nuclear testing occurred (primarily at Pahute Mesa), are 40 kilometers (25 miles) and 30 kilometers (19 miles), respectively, north of Yucca Mountain. A single nuclear test with multiple detonations spaced in a row occurred in Area 30 of the Nevada Test Site (DIRS 101811-DOE 1996, p. 4-17) about 21 kilometers (13 miles) north of the repository site. The flow of groundwater from these areas could be to the south. Because of the distances, there is no reason to believe that contaminants could move as far as Yucca Mountain before repository closure, with the possible exception of tritium. In addition, DOE modeling suggests that groundwater flow patterns from these test areas to the north skirt the Yucca Mountain area (DIRS 103021-DOE 1997, p. ES-28). This is similar to the conceptual model of groundwater flow from more recent U.S. Geological Survey efforts (Figure 3-8), which show that Pahute Mesa is in the dividing area between the Pahute Mesa-Oasis Valley Groundwater Basin and the Alkali Flat-Furnace Creek Groundwater Basin where Yucca Mountain is located. The Survey model describes water from Pahute Mesa as contributing flow to the southwest through Oasis Valley (skirting Yucca Mountain) as well as to the south through the Fortymile Canyon Section (DIRS 173179-Belcher 2004, pp. 152 and 154). Chapter 8 of this Repository SEIS discusses the potential for long-term migration of radionuclides in the groundwater system to result in cumulative radiation impacts from nuclear testing and repository actions.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

The region of influence for biological resources and soils is the area that contains all potential surface disturbances that would result from the Proposed Action and some additional area to evaluate local animal populations. This region is roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (150,000 acres). DOE has expanded the region of influence for biological resources and soils from that in the Yucca Mountain FEIS to include land proposed for an access road from U.S. Highway 95 and for construction of offsite facilities. This offsite area would include Bureau of Land Management lands between the southern boundary of the analyzed land withdrawal area and U.S. Highway 95 (Figure 3-1). The offsite area covers about 37 square kilometers (9,100 acres).

In the Yucca Mountain FEIS, DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence and the broader region. The data suggested that the plants and animals in the Yucca Mountain region were typical of species in the Mojave and Great Basin deserts. As reported in the Yucca Mountain FEIS, DOE surveyed the region for naturally occurring wetlands and studied soil characteristics in the region, which included thickness, water-holding capacity, texture, and erosion hazard.

Beginning in 1982 with site investigation, DOE has conducted extensive field surveys to characterize the biological and soil resources in the vicinity of Yucca Mountain (DIRS 104593-CRWMS M&O 1999, all; DIRS 104592-CRWMS M&O 1999, all). DOE used the results of these studies to assess the impacts of site characterization in the Yucca Mountain FEIS analysis to understand and predict possible impacts from similar activities that would occur during repository construction and operations. For this Repository SEIS, DOE analyzed the results of field surveys and habitat data that have become available since completion of the Yucca Mountain FEIS. This Repository SEIS includes information from more recent lists of and surveys for special-status species and the results of a new land cover mapping effort.

3.1.5.1 Biological Resources

3.1.5.1.1 *Vegetation*

In the Yucca Mountain FEIS, DOE used data from two sources to describe land cover types in the analyzed land withdrawal area: a statewide classification and a detailed, field-validated classification of the area around the Yucca Mountain site. DOE has reassessed land cover in the region of influence using data from the *Southwest Regional Gap Analysis Project* (DIRS 174324-NatureServe 2004, all), which were not yet available when the FEIS was completed and which describe land cover at a finer level of detail than previous land cover mapping efforts. In addition, the species composition results of field studies DOE performed in and near the analyzed land withdrawal area (conducted after the FEIS was completed, and as summarized in the Rail Alignment EIS) are consistent with the results in the Yucca Mountain FEIS and the results of subsequent analyses of Southwest Regional Gap Analysis Project land cover data.

SOUTHWEST REGIONAL GAP ANALYSIS PROJECT

This 2004 project was a multi-institutional effort to map and assess biodiversity for approximately 1.45 million square kilometers (560,000 square miles) in the southwestern United States. One task of this project was the development of a land cover map for the region.

An **ecoregion** is a relatively discrete set of ecosystems characterized by certain plant communities or assemblages.

Mapping zones are biogeographically unique areas the Southwest Regional Gap Analysis Project derived from existing ecoregion maps using a combination of topographic and soil information, which it then truncated at state boundaries. Mapping zones are subunits of ecoregions.

Using previously defined *ecoregions* in the southwestern United States that are based on physical and biological similarities, the Southwest Regional Gap Analysis Project developed *mapping zones* to facilitate land cover delineation. By analyzing satellite imagery and field data, the Southwest Regional Gap Analysis Project classified geographic areas in each mapping zone based on land cover types and generated maps of land cover type occurrence. The project classified naturally vegetated land cover with an ecological systems classification and developed and described land cover types based on dominant vegetation, physical characteristics of the land, hydrology, and climate (DIRS 176369-Lowry et al. 2005, all; DIRS 173051-Comer et al. 2003, all). Ecological systems are recurring groups of biological communities in similar physical environments with similar dynamic ecological processes, such as fire or flooding. To identify land cover types in the region of influence, the project overlaid digital maps of the types in the mapping zones with a digital map of the repository region of influence.

The analyzed land withdrawal area is in the Mojave Desert ecoregion but, because it is near the southern boundary of the Great Basin Desert ecoregion, land cover types common to both deserts occur in the area. Whereas most of the land withdrawal area and all of the offsite area to the south are in the Mojave mapping zone, the northern portion of the land withdrawal area is in the Nellis mapping zone, which reflects the transition between the Mojave and Great Basin deserts.

DOE identified 19 land cover types in the region of influence (Table 3-6). Plant communities at lower elevations are typical of the Mojave Desert, and communities at higher elevations, generally at the northern end of the analyzed land withdrawal area, are typical of the transition zone between the Mojave

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Desert and the cooler Great Basin Desert. Table 3-6 lists the *native species* of plants that are typical components of these land cover types.

> **PLANT TERMS**
>
> **Native species:** With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem (Executive Order 13112).
>
> ***Nonnative species*:** A species found in an area where it has not historically been found.
>
> **Invasive species:** An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112).
>
> ***Noxious weeds*:** Any species of plant which is, or is likely to be, detrimental or destructive and difficult to control or eradicate (Nevada Revised Statutes 555.005).

In addition to shrubs and grasses, biological soil crusts are an important component to the Mojave and Great Basin ecosystems. Biological crusts consist of multiple species of lichen, moss, cyanobacteria, and algae that live on top of the soil surface, binding with soil particles and forming a cohesive mat or crust on the surface of dry landscapes (DIRS 181866-Belnap 2006, p. 1). Cyanobacteria are the dominant component of crusts in the Mojave Desert, while soil lichen and moss species tend to be limited. Biological crusts (if present) could play an important role in maintaining the health of some of the desert vegetation communities listed in Table 3-6, including but not limited to facilitating water infiltration, retaining soil moisture, and reducing soil loss from wind and water erosion (DIRS 181957-Kaltenecker and Wicklow-Howard 1994, pp. 3 to 8). Biological crusts are highly sensitive to surface disturbance and are easily destroyed. They probably occur in the region of influence in some areas where there has been no surface disturbance.

About six *invasive species* commonly occur in the region of influence. These species are so prevalent and opportunistic that it is no longer practical or possible to eliminate them from the environment, although it is possible to control their spread into new areas. Some species often colonize areas that construction or traffic have disturbed. The most common include red brome (*Bromus rubens*), Russian thistle (*Salsola* spp.), tumble mustard (*Sisymbrium altissimum*), halogeton (Halogeton glomeratus), redstem stork's bill (*Erodium cicutarium*), and Arabian schismus (*Schismus arabicus*). Red brome is the most abundant nonnative species in the region of influence and the surrounding area. Approximately 20 other nonnative, invasive species could be present to a lesser degree; in many cases these species have been or might have been eliminated in particular areas. None of these species is on the State of Nevada's Noxious Weed List (DIRS 174543-NDOA 2005, all).

3.1.5.1.2 *Wildlife*

This section summarizes, incorporates by reference, and updates Section 3.1.5.1.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 3-72) for wildlife occurrence in the analyzed land withdrawal area and presents new information from studies and investigations that continued after completion of the Yucca Mountain FEIS. Thirty-six species of mammals are known to occur in and around Yucca Mountain. Rodents are the most abundant mammals, with 17 documented species. The most common rodents at Yucca Mountain are Merriam's kangaroo rats (*Dipodomys merriami*) and pocket mice, with long-tailed pocket mice (*Chaetodipus formosus*) at middle and higher elevations and little pocket mice (*Perognathus longimembris*) at lower elevations. Other wildlife that occurs in the area includes:

Table 3-6. Land cover types in the region of influence.

Land cover type	Percent of region of influence	Description
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	57	Occurs in broad valleys, lower washes, and low hills. Creosote bush (*Larrea tridendata*) and white bursage (*Ambrosia dumosa*) are typical dominants.
Mojave Mid-Elevation Mixed Desert Scrub	27	Common on lower foothill slopes in the transition zone into the southern Great Basin. Dominant species include blackbrush (*Coleogyne ramosissima*), Eastern Mojave (California) buckwheat (*Eriogonum fasciculatum*), Nevada jointfir (*Ephedra nevadensis*), spiny hopsage (*Grayia spinosa*), spiny menodora (*Menodora spinescens*), buck-horn cholla (*Cylindropuntia acanthocarpa*), big galleta (*Pleuraphis rigida*), Mexican bladdersage (*Salazaria mexicana*), Joshua tree (*Yucca brevifolia*), or Mojave yucca (*Yucca schidigera*).
Inter-Mountain Basins Semi-Desert Shrub Steppe	8.0	Occurs on alluvial fans and flats with moderate to deep soils. Common grasses include Indian ricegrass (*Achnatherum hymenoides*), blue grama (*Bouteloua gracilis*), saltgrass (*Distichlis spicata*), needle and thread (*Hesperostipa comata*), James' galleta (*Pleuraphis jamesii*), Sandberg bluegrass (*Poa secunda*), and alkali sacaton (*Sporobolus airoides*). Common shrubs include fourwing saltbush (*Atriplex canescens*), big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* and *Ericameria* spp.), jointfir, broom snakeweed (*Gutierrezia sarothrae*), and winterfat (*Krascheninnikovia lanata*).
Sonora-Mojave mixed salt desert scrub	2.0	Occurs in saline basins in the Mojave Desert, often around playas. Typical vegetation includes saltbush species such as fourwing saltbush or cattle saltbush (*Atriplex polycarpa*) and other salt-tolerant species.
North American Warm Desert Volcanic Rockland	1.6	Restricted to barren and sparsely vegetated volcanic ground such as basalt lava and tuff. Scattered creosote bush, saltbush, or other desert shrubs are typical.
Great Basin Xeric Mixed Sagebrush Shrubland	1.4	Occurs on dry flats, alluvial fans, rolling hills, rocky hill slopes, saddles, and ridges of the Great Basin. Dominated by black sagebrush (*Artemisia nova*) or little sagebrush (*Artemisia arbuscula*), and can be accompanied by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) or yellow rabbitbrush (*Chrysothamnus viscidiflorus*).
North American Warm Desert Bedrock Cliff and Outcrop	1.1	Occurs in foothills, includes barren to sparsely vegetated landscapes of steep cliff faces, narrow canyons, and smaller rock outcrops, including unstable scree and talus slopes typically below cliff faces. Species include desert and succulent species such as teddybear cholla (*Cylindropuntia bigelovii*).

Table 3-6. Land cover types in the region of influence (continued).

Land cover type	Percent of region of influence	Description
Inter-Mountain Basins Mixed Salt Desert Scrub	0.63	Occurs in saline desert basins and alluvial slopes. Vegetation includes one or more saltbush species such as shadscale saltbush (*Atriplex confertifolia*), fourwing saltbrush, or cattle saltbrush, accompanied by species such as Wyoming big sagebrush, yellow rabbitbrush, rubber rabbitbrush (*Ericameria nauseosa*), Nevada jointfir, spiny hopsage, winterfat, pale wolfberry (*Lycium pallidum*), or horsebrush (*Tetradymia* spp.).
Inter-Mountain Basins Cliff and Canyon	0.61	Occurs in foothills, includes barren and sparsely vegetated landscapes of steep cliff faces, narrow canyons, and smaller rock outcrops, including unstable scree and talus slopes typically below cliff faces. Widely scattered trees and shrubs include limber pine (*Pinus flexilis*), singleleaf pinyon (*Pinus monophylla*), juniper (*Juniperus* spp.), big sagebrush, antelope bitterbrush (*Purshia tridentata*), curl-leaf mountain mahogany (*Cercocarpus ledifolius*), jointfir, and other species often common in adjacent plant communities.
Inter-Mountain Basins Big Sagebrush Shrubland	0.57	Occurs in broad basins between mountain ranges and in foothills. Dominated by basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), Wyoming big sagebrush, or both.
Great Basin Pinyon-Juniper Woodland	0.33	Occurs on warm dry sites on mountain slopes, mesas, plateaus, and ridges. Dominated by single leaf pinyon and Utah juniper (*Juniperus osteosperma*), or both.
North American Warm Desert Active and Stabilized Dune	0.23	Consists of unvegetated to sparsely vegetated sand dunes.
Inter-Mountain Basins Semi-Desert Grassland	Less than 0.1	Occurs on dry plains and mesas. Vegetation consists of very drought-resistant grasses and shrubs.
Inter-Mountain Basins Greasewood Flat	Less than 0.1	Occurs near drainages or in rings around playas. Dominated or at least accompanied by greasewood (*Sarcobatus vermiculatus*).
North American Warm Desert Playa	Less than 0.1	Consists of barren and sparsely vegetated playas. Vegetation is very salt-tolerant when present.
Invasive Annual Grassland	Less than 0.1	Consists of invasive grasses including red brome (*Bromus rubens*).
North American Warm Desert Lower Montane Riparian Woodland and Shrubland	Less than 0.1	Occurs in riparian corridors along perennial and seasonally intermittent streams. Vegetation is a mix of riparian trees and shrubs.
Inter-Mountain Basins Montane Sagebrush Steppe	Less than 0.1	Occurs on ridges and mountain slopes. Vegetation is typically dominated by sagebrush species.
North American Warm Desert Wash	Less than 0.1	Restricted to intermittently flooded washes. Vegetation composition is highly variable.

Sources: DIRS 174324-NatureServe 2004, all; DIRS 179926-USGS 2004, all.

- Three species of rabbit—desert cottontail (*Sylvilagus audubonii*), mountain cottontail (*Sylvilagus nuttallii*), and black-tailed jackrabbits (*Lepus californicus*);
- Seven carnivores—kit foxes (*Vulpes macrotis*) (formerly combined with *Vulpes velox*) and coyotes (*Canis latrans*) (the most common), long-tailed weasels (*Mustela frenata*), badgers (*Taxidea taxus*), western spotted skunks (*Spilogale gracilis*), bobcats (*Lynx rufus*), and mountain lions (*Puma concolor*);
- Two ungulates—mule deer (*Odocoileus hemionus*) and wild burros (*Equus asinus*); and
- Several species of bats.

There are no known wild horses at or near Yucca Mountain. As defined by Nevada Administrative Code 503.020 and 503.025, four species of game mammals occur in the analyzed land withdrawal area—desert cottontail, mountain cottontail, mule deer, and mountain lions—and there are two known species of furbearers—kit foxes and bobcats.

Twenty-seven known species of reptiles, including 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*), occur at and near Yucca Mountain. The most abundant lizards are the side-blotched lizard (*Uta stansburiana*) and the western whiptail (*Cnemidophorus tigris*), and the most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). The common chuckwalla (*Sauromalus ater*) (formerly *Sauromalus obesus*), the largest nonvenomous lizard in the United States, is locally common in some rocky areas in the region of influence. There are no known amphibians at Yucca Mountain.

Investigators have recorded more than 120 species of birds at Yucca Mountain and in the surrounding region, including 22 species that are believed to nest regularly in the area and 15 species of raptors (DIRS 104593-CRWMS M&O 1999, p. 3-10). Three species of game birds (Nevada Administrative Code 503.045) have been seen in the land withdrawal area: Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning dove (*Zenaida macroura*).

Because most of the habitat in the offsite area to the south is similar to the lower elevation portions of the analyzed land withdrawal area, many of the same species are likely to occur there, especially rodents, rabbits, and reptiles. In addition, the Bureau of Land Management has designated land in the Striped Hills near the eastern edge of this offsite area as winter habitat for desert bighorn sheep (*Ovis canadensis nelsoni*) (DIRS 103079-BLM 1998, Map 3-7).

3.1.5.1.3 *Special-Status Species*

This Repository SEIS considers the following special-status animal and plant species: (1) species that the U.S. Fish and Wildlife Service lists or proposes to list as endangered or threatened under the *Endangered Species Act*, as amended (16 U.S.C. 1531 et seq.) or species the Service has designated as species of concern under the Act; (2) species the U.S. Bureau of Land Management considers sensitive as designated by the Bureau's State Director in Nevada (DIRS 172900-BLM 2003, all); (3) flora the State of Nevada classifies as fully protected (Nevada Administrative Code 527); and (4) wild mammals, birds, fish, reptiles, and amphibians that the State of Nevada classifies as endangered, threatened, or sensitive

(Nevada Administrative Code 503). This section summarizes, incorporates by reference, and updates Section 3.1.5.1.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-73 and 3-74).

SPECIAL-STATUS SPECIES

Endangered Species Act
The Act classifies an ***endangered species*** as being in danger of extinction throughout all or a significant part of its range.

The Act classifies a **threatened species** as likely to become endangered in the foreseeable future.

The Secretary of the Interior designates **proposed species** for inclusion in the lists of threatened and endangered species.

Nevada Administrative Code 503 and 527
The state designates special-status animal species as endangered, threatened, protected, and sensitive under Nevada Administrative Code 503. Fully protected plants that are declared to be critically endangered and threatened with extinction are protected under Nevada Administrative Code 527.

Bureau of Land Management
The Bureau's State Director for Nevada designates ***sensitive species,*** which are in addition to the above special-status species.

One animal species at Yucca Mountain, the Mojave population of the desert tortoise, is a *threatened species* under the *Endangered Species Act*. Yucca Mountain is at the northern edge of the range of the desert tortoise, and the abundance of tortoises at Yucca Mountain is low or very low in comparison with other portions of its range (DIRS 155970-DOE 2002, p. 3-73). Since the completion of the Yucca Mountain FEIS, additional surveys covering approximately 1.3 square kilometers (320 acres) for desert tortoises and other special-status species have occurred in the Yucca Mountain area (DIRS 181672-Morton 2007, p. 1). Most of those surveys were in Midway Valley within about 2 kilometers (1.2 miles) of the Exploratory Studies Facility. Neither those surveys nor other work at Yucca Mountain have resulted in observations of other special-status species.

Since completion of the Yucca Mountain FEIS, DOE has examined an updated version of the Nevada Natural Heritage Program's element occurrence database to identify any previously undocumented observations of special-status species within the region of influence. Table 3-7 lists the documented special-status species within the region of influence and the authorities that protect them. All migratory birds are classified by the State of Nevada as protected. In addition to these species, individual bald eagles (*Haliaeetus leucocephalus*) occasionally migrate through the region; this species is classified as endangered by the State of Nevada, and although recently removed from listing under the *Endangered Species Act* the species is still protected under the federal *Bald and Golden Eagle Protection Act* and has been seen once at the Nevada Test Site (DIRS 155970-DOE 2002, p. 3-73). Bald eagles are rare in the region and have not been seen at Yucca Mountain.

3.1.5.1.4 *Wetlands*

This section summarizes and incorporates by reference Section 3.1.5.1.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 3-74). As the FEIS reported, there are at present no naturally occurring wetlands at Yucca Mountain that would require regulation under Section 404 of the *Clean Water Act,* as

Table 3-7. Special-status species observed in the region of influence.

Common name (scientific name)	Status	Evaluation of potential for occurrence at Yucca Mountain[a]
	Birds[b]	
Golden eagle (*Aguila chrysaetos*)	BLM Sensitive	Present
Short-eared owl (*Asio flammeus*)	BLM Sensitive	Present
Long-eared owl (*Asio otus*)	BLM Sensitive	Present
Western burrowing owl *(Athene cunicularia hypugaea)*	BLM Sensitive	Present
Ferruginous hawk (*Buteo regalis*)	BLM Sensitive	Present
Swainson's hawk (*Buteo swainsoni*)	BLM Sensitive	Present
Prairie falcon (*Falco mexicanus*)	BLM Sensitive	Present
Loggerhead shrike *(Lanius ludovicianus)*	Nevada, BLM Sensitive	Present
Long-billed curlew (*Numenius americanus*)	BLM Sensitive	Rare
LeConte's thrasher (*Toxostoma lecontei)*	BLM Sensitive	Present
	Mammals	
Pallid bat (*Antrozous pallidus*)	Nevada Protected, BLM Sensitive	Common
Hoary bat (*Lasiurus cinereus*)	BLM Sensitive	Rare
California myotis (*Myotis californicus*) or Small-footed myotis (*Myotis ciliolabrum)*	BLM Sensitive	Common (The two species could not be confidently distinguished in the field.)
Fringed myotis (*Myotis thysanodes*)	Nevada Protected, BLM Sensitive	Rare
Long-legged myotis (*Myotis volans*)	BLM Sensitive	Rare
Western pipistrelle (*Pipistrellus hesperus)*	BLM Sensitive	Common
Brazilian free-tailed bat (*Tadarida brasiliensis*)	Nevada Protected, BLM Sensitive	Rare
	Reptiles	
Desert tortoise (*Gopherus agassizii)*	Federal Threatened, Nevada Threatened	Present
Western red-tailed skink (*Eumeces gilberti rubricaudatus*)	BLM Sensitive	Rare
Common chuckwalla (*Sauromalus ater*) (formerly *Sauromalus obesus*)	BLM Sensitive	Present
	Invertebrates	
Giuliani's dune scarab (*Pseudocotalpa giulianii*)	BLM Sensitive	Present, only in dune habitat south of Yucca Mountain.

Source: DIRS 181672-Morton 2007, p.1.

a. Common = known to be common in the region of influence; present = known to occur in the region of influence but at low abundance; rare = potentially occurs in the region of influence but very limited number of documented sightings.

b. The State of Nevada classifies all migratory birds as protected.

BLM = Bureau of Land Management.

amended (33 U.S.C. 1344 et seq.) (DIRS 155970-DOE 2002, p. 3-74). One manmade well pond in the analyzed land withdrawal area has riparian vegetation. Fortymile Wash and some of its tributaries could be classified as waters of the United States under the Act. On June 5, 2007, the EPA and the U.S. Army Corps of Engineers released interim guidance that addresses the jurisdiction over waters of the United States in light of recent Supreme Court decisions. Based on this new guidance, it is less likely that the ephemeral washes and riverbeds in this area would be considered waters of the United States. For the proposed construction actions in these washes, the Corps of Engineers would have to determine the limits of jurisdiction under Section 404 of the *Clean Water Act*.

3.1.5.2 Soils

This section summarizes, incorporates by reference, and updates Section 3.1.5.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-74 to 3-76). DOE performed a soil survey in an 18-square-kilometer (4,400-acre) area around Midway Valley, which includes most of the areas where soil disturbances for the Proposed Action would occur, and performed a more general survey over the entire Yucca Mountain region (DIRS 104592-CRWMS M&O 1999, all). Both surveys identified only two *soil orders*, and the Midway Valley survey identified 17 *soil series* and seven *soil map units* (Table 3-8).

SOIL TERMS

Duripan: A subsurface layer held together (cemented) by silica, usually containing other accessory cements.

Hydric: Describes soils that are characterized by the presence of considerable moisture.

Indurated: Hardened, as in a subsurface layer that has become hardened.

Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

Prime farmland: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not eligible). It has the soil quality, growing season, and moisture supply necessary for the economic production of sustained high yields of crops when treated and managed (including water management) in accordance with acceptable farming methods (*Farmland Protection Policy Act*, as amended; 7 U.S.C. 4201 et seq.).

Soil map unit: A conceptual group of one or more map delineations identified by the same name in a soil survey that represent similar landscape areas that consist of either (1) the same kind of component soils, with inclusions of minor or erratically dispersed soils, or (2) two or more kinds of component soils that might or might not occur together in various delineations but that have similar special use and management properties.

Soil order: The broadest category of soil classification, identified by the presence or absence of diagnostic layers, or horizons, which have specific physical, chemical, and biological properties.

Soil series: The lowest category of soil taxonomy with the most restrictive classification of soil properties.

None of these soils is *prime farmland*, and there are no *hydric* soils at Yucca Mountain. None of the soils at Yucca Mountain qualifies for groups one or two of the Natural Resources Conservation Service's wind erodibility classification, which means that these soils are not highly susceptible to wind erosion.

Yucca Mountain soils derive from underlying volcanic rocks and mixed alluvium that is mostly of volcanic origin, and in general have low water-holding capacities. DOE has sampled and analyzed surface soils for radiological constituents. The Department has maintained records of spills or releases of nonradioactive materials both to meet regulatory requirements and to provide a baseline for the Proposed Action. DOE's *Distribution of Natural and Man-Made Radionuclides in Soil and Biota at Yucca Mountain, Nevada* summarizes existing radiological conditions in soils from 98 surface samples from within 16 kilometers (9.9 miles) of the Exploratory Studies Facility (DIRS 146183-CRWMS M&O 1996, all). The results of that analysis, in comparison with other parts of the world, indicate average levels of naturally occurring uranium-238 decay products and above-average levels of naturally occurring

Table 3-8. Soil mapping units at Yucca Mountain.

Map unit	Percent	Geographic setting	Soil characteristics
Upspring-Zalda	11	Mountain tops and ridges. Soils on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types.	Typically shallow (10 to 51 cm) to bedrock or thin duripan over bedrock. Well to excessively drained, low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard.
Gabbvally-Downeyville-Talus	8	North-facing mountain side slopes. Talus (stone-sized rock) random throughout unit in long, narrow, vertically oriented accumulations.	Shallow (10 to 36 cm) to bedrock. Permeability moderate to moderately rapid. Moderate to rapid runoff potential, well drained, low available water-holding capacity, and moderate erosion hazard.
Upspring-Zalda-Longjim	27	Mountain side slopes. Soils on south, east, and west slopes, and on moderately sloping alluvial deposits below side slopes.	Shallow (10 to 51 cm) to bedrock or thin duripan over bedrock. Well to excessively drained, moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard.
Skelon-Aymate	22	Alluvial fan remnants. Soils on gently to strongly sloping summits and upper side slopes.	Moderately deep (51 to 102 cm) to indurated duripan or petrocalcic layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard.
Strozi variant-Yermo-Bullfor	7	Alluvial fan remnants. Soils on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages.	Moderately deep (51 to 102 cm) to deep (102 cm). Well drained, rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard.
Jonnic variant-Strozi-Arizo	12	Dissected alluvial fan remnants. Soils formed in alluvium from mixed volcanic sources on fan summits, moderately sloping fan side slopes, and inset fans.	Moderately deep (36 to 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. Slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard.
Yermo-Arizo-Pinez	13	Inset fans and low alluvial side slopes in mountain canyons and drainages between fan remnants. Soils on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills.	Deep (more than 102 cm), sometimes over indurated duripan. Well drained, very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard.

Source: DIRS 155970-DOE 2002, p. 3-75.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
cm = centimeter.

potassium-40 and thorium-232 decay products. The higher-than-average values could be due to the origin of the soil at the site from tuffaceous igneous rocks. In addition, the studies detected small concentrations of strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

3.1.6 CULTURAL RESOURCES

The region of influence for cultural resources includes the analyzed land withdrawal area, land that DOE has proposed for an access road from U.S. Highway 95, and land where DOE would construct offsite facilities. The Department would construct a portion of the proposed access road from U.S. Highway 95 on Bureau of Land Management land that Nye County currently controls. The analysis for this Repository SEIS assumed a location on Bureau of Land Management land near Gate 510 of the Nevada Test Site for construction of the offsite facilities. Federal agencies manage most of the land in the region. This section summarizes, incorporates by reference, and updates Section 3.1.6 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-76 to 3-82). In addition, these sections present environmental data that have become available since DOE completed the Yucca Mountain FEIS and that are pertinent to cultural resources and the associated impact analysis.

3.1.6.1 Archaeological and Historic Resources

The Yucca Mountain FEIS reported approximately 830 archaeological sites in the analyzed land withdrawal area, based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno, Nevada, and at the Harry Reid Center for Environmental Studies at the University of Nevada, Las Vegas. Most of these archaeological sites are small scatters of lithic (stone) artifacts that usually comprise fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. Temporally and culturally diagnostic artifacts can include projectile points and ceramic artifacts that can reference specific periods or cultural groups.

Since DOE completed the Yucca Mountain FEIS, it has refined the number of sites in the analyzed land withdrawal area to approximately 532 archaeological sites and 553 isolated artifacts (DIRS 172306-Rhode 2004, all). The change in number is due to the combination of some of the sites with the gathering of additional information that showed the sites were part of the same artifact complex. In addition, the revised number reflects the archaeological resources that recent investigations for the U.S. Highway 95 access road recorded. These 1,085 archaeological sites and isolated artifacts strictly pertain to the current analyzed land withdrawal area of the Proposed Action. None of the archaeological sites has been listed on the *National Register of Historic Places*; DOE, in consultation with the Nevada State Historic Preservation Office, has determined that the large majority of sites and isolated artifacts are not eligible for inclusion in the *National Register*. The Department, in consultation with the Nevada State Historic Preservation Office, has recommended 232 archaeological sites for inclusion in the *National Register* and manages these sites accordingly. The site types in the analyzed land withdrawal area are temporary camps, extractive localities, processing localities, caches, stone tool manufacture stations, and historic sites.

Since the completion of the Yucca Mountain FEIS, there have been intensive surveys, assessments, and periodic monitoring to identify, characterize, and better evaluate cultural resources in the analyzed land withdrawal area. A draft programmatic agreement among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Office has been prepared for cultural resources management related to activities that would be associated with development of a repository at Yucca Mountain. While this agreement is in ongoing negotiation among the concurring parties, DOE is abiding by Section 106 of the *National Historic Preservation Act of 1966* (16 U.S.C. 470) process.

3.1.6.2 American Indian Interests

3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In the Yucca Mountain FEIS, DOE discussed its program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with tribes and organizations. Within this program, 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of appointed tribal representatives who are responsible for presentation of their respective tribal concerns and perspectives to DOE. The Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah have cultural and historic ties to the Yucca Mountain area.

DOE held Tribal Update Meetings for members of the Consolidated Group of Tribes and Organizations between October 2004 and January 2005 (DIRS 174205-Kane et al. 2005, all). The Consolidated Group recommended additional studies to address eight issues of concern related to potential adverse impacts to the American Indian landscape. Additional recommendations involved increasing and ensuring consistent and effective communication between DOE and the Consolidated Group.

3.1.6.2.2 *American Indian Views of the Affected Environment*

The Yucca Mountain FEIS summarized American Indian views of the affected environment. In general, American Indians believe they are the original inhabitants of their homelands since the beginning of time. They assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain region. The American Indian people believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms. Equally important are water resources and minerals. According to American Indian people, the Yucca Mountain region is part of the lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.

3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain area for this Repository SEIS, DOE determined that it should base the region of influence on the distribution of potential residences of employees. At present, few Yucca Mountain Project employees work at the Yucca Mountain site. The Department would transfer most offsite Project positions to the Yucca Mountain site as the construction and operations of the repository began. Therefore, for this Repository SEIS, DOE used historical, rather than current, data to forecast the future residential distribution of Yucca Mountain Project workers. This section summarizes, incorporates by reference, and updates Section 3.1.7 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-82 to 3-93) and provides new information, as applicable, from studies and investigations that continued after DOE completed the FEIS.

In 1994, when the total Yucca Mountain site employment was approximately 1,600 workers, about 98 percent of the workers, including those assigned to the Nevada Test Site location, lived in Clark and Nye counties. Since late 1995, Yucca Mountain site employment numbers have dropped significantly. DOE assumes that the historical pattern of residential distribution of onsite workers in 1994 reflects the projected residential distribution for the Proposed Action because 1994 is the most recent year where onsite employment most nearly reflects expected employment for the Proposed Action. The migration patterns of Yucca Mountain Project workers who moved to Nevada from 1986 to March 2005 reinforce this expected pattern. Of the 3,866 individuals (1,740 workers and 2,126 dependents) who moved to Nevada as a direct result of Project employment, 3,808 chose to live in Clark County and 56 chose to live in Nye County, primarily in Pahrump and Mercury (DIRS 180788-BSC 2005, pp. 3-20 and 3-21). Therefore, DOE has selected Clark and Nye counties as the region of influence for socioeconomic resources for this Repository SEIS (Figure 3-14). The Yucca Mountain FEIS included Lincoln County although less than 1 percent of the workforce lived in Lincoln County. Lincoln County is not a part of the Repository SEIS region of influence because so few Yucca Mountain Project workers lived there in 1994 and so few recent project migrants chose to live there. DOE recognizes that historical trends might not reflect future patterns and therefore presents an alternative residential distribution pattern in Appendix A of this Repository SEIS.

Clark County contains the cities of Las Vegas, Boulder City, Henderson, Mesquite, North Las Vegas, and other communities (DIRS 181749-Nevada State Demographer n.d., all). Based on a count of workers in a 1994 data report, 79 percent of the Yucca Mountain site workers lived in Clark County, and approximately 19 percent lived in Nye County (Table 3-9).

DOE used the Regional Economic Models, Inc. (REMI), economic-demographic forecasting computer model, Version 9, Policy Insight, to estimate the baselines for population, employment, and three economic measures: Gross Regional Product, Real Disposable Personal Income, and State and local government spending. For this Repository SEIS, the REMI model projected the baselines from 2005 to 2067 for the two counties in the region of influence and for the State of Nevada. Table 3-10 lists the baseline information for the counties in the region of influence and for Nevada.

The version of the REMI model that DOE used for the Yucca Mountain FEIS contained historical data through 1997. DOE developed the baseline data for this Repository SEIS using REMI *Policy Insight Version* 9.0, which uses historical data through 2004 and updates DOE received from local and state sources. Employment and population estimates and projections incorporate data from the Nevada State Demographers Office, Nevada Department of Employment, Training, and Rehabilitation, and the University of Nevada-Las Vegas Center for Business and Economic Research.

This section cites information, when available, from the Nevada State Demographer's Office and updates gathered by the U.S. Census Bureau. DOE developed the baselines with input from the State of Nevada and local sources. The Department used the baselines to project of impacts to socioeconomic parameters, which include population and employment.

3.1.7.1 Population

From 1990 to 2000, Nevada had a total growth of 64 percent (DIRS 174418-Nevada State Demographer n.d., all); the overall growth of the United States (DIRS 181012-Bureau of the Census 1990, all) was 13 percent. The population of the region of influence grew by 81 percent from 1990 to 2000, an average of almost 64,000 new residents annually. In 2000, the estimated population of the region of influence was about 1.43 million (DIRS 174418-Nevada State Demographer n.d., all).

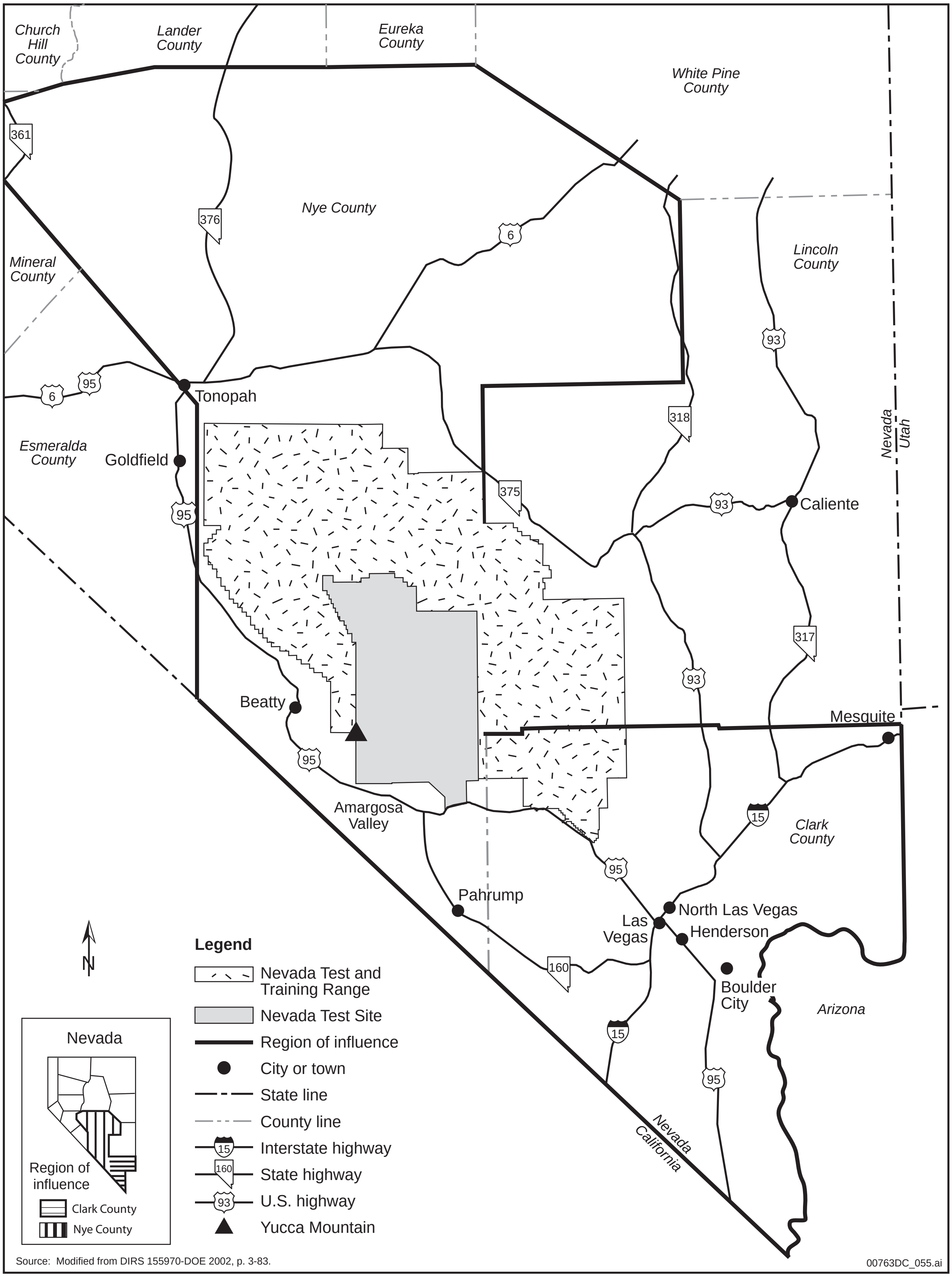

Figure 3-14. Socioeconomic region of influence for this Repository SEIS.

Table 3-9. Distribution by place of residence of Yucca Mountain site employees.

Place of residence	Onsite workers	Percent of total
Clark County	1,268	79
Nye County	308	19
Total region of influence	1,576	98
Outside region of influence	36	2
Total workers	1,612	100

Source: DIRS 104957-DOE 1994, p. 2-9.
Note: Onsite Yucca Mountain Project employees worked either at the Yucca Mountain Repository or on the Nevada Test Site. All onsite workers were employed in Nye County.

In 2000, the population of Clark County was about 1.4 million people, which indicates an 81-percent growth rate during the 1990s (DIRS 174418-Nevada State Demographer n.d., all). Las Vegas, the county seat, is by far the largest population base, with about 480,000 residents in 2000. Boulder City had approximately 15,000 residents, Henderson had about 180,000 residents, Mesquite had 10,000 residents, and North Las Vegas had about 120,000 residents in the same year. By 2005, Las Vegas had a population of 570,000, Boulder City had 15,200, Henderson had 241,000, Mesquite had 16,000, and North Las Vegas had a population of 180,000.

In 2000, the population of Nye County was 33,000. As in Clark County, Nye County experienced an 81-percent growth during the 1990s (DIRS 174418-Nevada State Demographer n.d., all). Today, Pahrump, the county's largest population center, is experiencing explosive growth, due primarily to in-migrating retirees and its proximity to Las Vegas. Pahrump had a population of about 24,000 people in 2000 and more than 33,000 in 2005. The county seat of Tonopah had about 2,900 residents in 2000.

Although the annual growth rate in the region of influence has slowed in the last 5 years from the extraordinary pace of the 1990s, the population should continue to grow at a rate greater than 4.6 percent a year, about four times the national average, in this decade (DIRS 178610-Bland 2007, all). Clark County will continue to lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities and towns as well as unincorporated communities (Table 3-11). Clark County has five incorporated cities and numerous unincorporated but recognized communities. Nye County has no incorporated cities; the largest community is Pahrump. Communities in Nye County are widely separated and often surrounded by lands that are federally owned or held in trust; these communities, therefore, tend to have economies that are distinct from one another. Clark County has a population density of about 67 persons per square kilometer (170 per square mile) (DIRS 173533-Bureau of the Census 2005, all) and Nye County about 0.69 person per square kilometer (1.8 per square mile) (DIRS 172310-Bureau of the Census 2004, all). Nevada has about 7.0 persons, on average, per square kilometer (18 per square mile). As reflected in the sparse population density for Nye County, the region of influence consists of a metropolitan concentration in the Las Vegas area, with spotty occupancy in the remainder of the region. More than 85 percent of the land in Nevada is managed by the Federal Government (DIRS 181638-NDCNR n.d., all). Cities in metropolitan Clark County are well connected via established road systems and proximity to one another, but major population centers in Nye County, such as Pahrump and Tonopah, are almost 270 kilometers (170 miles) apart. Transportation systems must often weave around federally held lands with restricted access.

Table 3-10. Baseline values for population, employment, and economic variables, 2005 to 2067.

Variable	2005	2010	2015	2025	2035	2045	2067
Clark County							
Total population	1,820,000	2,260,000	2,650,000	3,170,000	3,540,000	3,950,000	5,000,000
Total employment	1,070,000	1,240,000	1,330,000	1,450,000	1,600,000	1,780,000	2,230,000
Spending by State and local governments (in billions of dollars)	6.5	8.5	11	13	16	18	23
Real Disposable Personal Income (in billions of dollars)	55	69	80	100	125	157	208
Total Gross Regional Product (in billions of dollars)	87	110	132	173	225	291	394
Nye County							
Total population	41,000	52,000	61,000	73,000	84,000	97,000	131,000
Total employment	17,000	19,000	21,000	23,000	25,000	28,000	37,000
Spending by State and local governments (in billions of dollars)	0.16	0.20	0.25	0.32	0.39	0.47	0.64
Real Disposable Personal Income (in billions of dollars)	1.0	1.3	1.4	1.8	2.2	2.8	4.0
Total Gross Regional Product (in billions of dollars)	1.1	1.3	1.6	2.1	2.7	3.5	5.0
All Nevada							
Total population	2,540,000	3,060,000	3,540,000	4,19,000	4,680,000	5,220,000	6,650,000
Total employment	1,520,000	1,720,000	1,830,000	2,000,000	2,180,000	2,410,000	3,030,000
Spending by State and local governments (in billions of dollars)	9.7	12	15	19	22	25	32
Real Disposable Personal Income (in billions of dollars)	77	96	110	140	170	210	280
Total Gross Regional Product (in billions of dollars)	118	147	177	233	301	389	527

Source: DIRS 178610-Bland 2007, all.
Note: Values are in 2006 dollars.

Table 3-11. Population of incorporated Clark County cities and selected unincorporated towns in Nye County, 1991 to 2005.

Jurisdiction	1991	1995	2000	2005
Clark County				
Boulder City	13,000	14,100	14,900	15,200
Henderson	77,500	115,000	179,000	241,000
Las Vegas	290,000	367,000	482,000	570,000
Mesquite	2,520	5,170	10,100	16,400
North Las Vegas	53,500	78,300	118,000	180,000
Nye County				
Amargosa	920	1,200	1,170	1,380
Beatty	1,800	1,900	1,150	1,000
Pahrump	8,800	15,000	24,200	33,200
Tonopah	3,600	3,400	2,830	2,610

Source: DIRS 180794-Hardcastle 2006, all
Note: Population numbers have been rounded to three significant figures.

The population growth in the State of Nevada and Clark County is expected to exceed average national trends through 2067. The population growth in Clark County is expected to grow more moderately through this decade and then slow to about 1.4 percent annually through 2067 (DIRS 178610-Bland 2007, all). Clark County will continue to house approximately 97 percent of the population in the region of influence. Nye County is expected to grow at an accelerated rate, with an average annual increase of approximately 2 percent (DIRS 178610-Bland 2007, all) through 2067. Figure 3-15 shows estimated populations for the region of influence and the State of Nevada, projected to 2065.

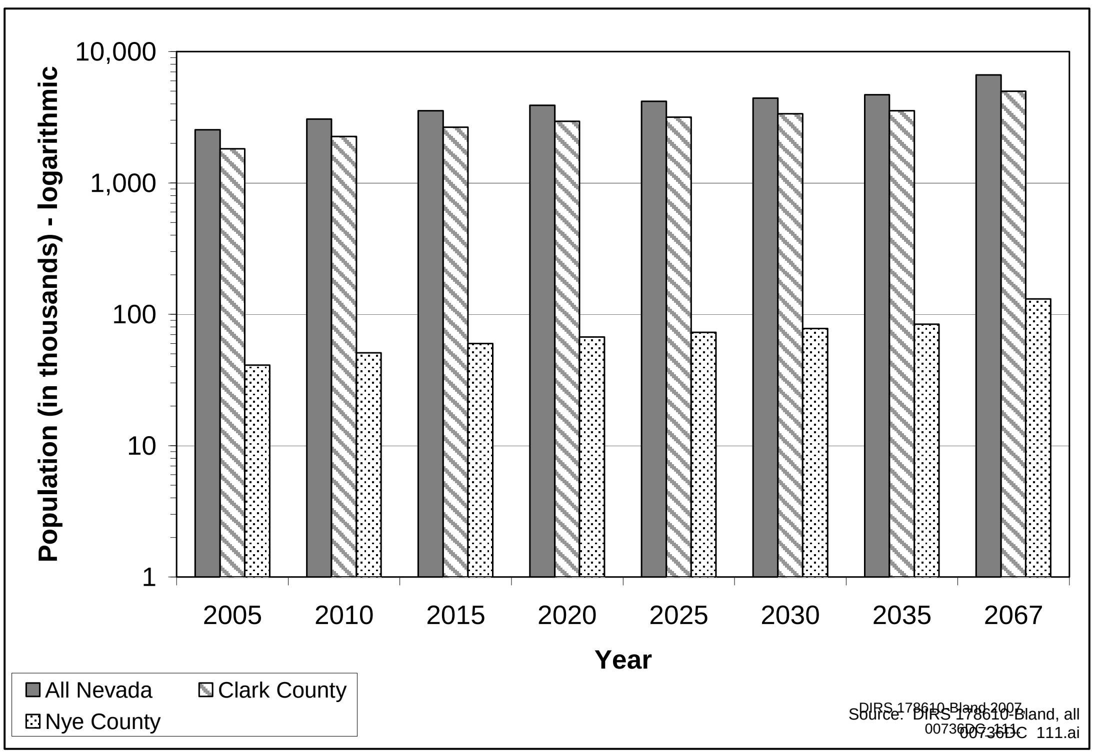

Figure 3-15. Estimated populations for the counties in the region of influence and the State of Nevada, projected to 2067.

3.1.7.2 Employment

In the region of influence, Clark County has the larger economy. In 2006, the estimated employment was 920,000; this constituted 98 percent of the regional employment and about 71 percent of the state employment. During the same year, Nye County had an employment base of approximately 13,000 (DIRS 178610-Bland 2007, all). Clark County is expected to continue to lead employment growth in the region of influence (DIRS 180734-NDETR 2007, all). The Leisure and Hospitality sector, which includes casinos, hotels, gaming, eating and drinking establishments, and amusement and recreation facilities, is the largest employment sector in Clark County, with 30 percent of the employment in June 2006 (DIRS 180712-NDETR 2006, all). The Professional and Business sector and Leisure and Hospitality sector are the largest employment sectors in the Nye County economy. In June 2006, these services comprised 40 percent of Nye County's employment. Retail trade made up an additional 14 percent (DIRS 180712-NDETR 2006, all).

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The Leisure and Hospitality industry drives this rapid growth. For each new hotel room, an employment multiplier effect creates an estimated 2.5 direct and indirect (composite) jobs. Despite an inventory of more than 130,000 rooms in December 2006, hotels consistently operate at 90-percent occupancy, reaching 95 percent on weekends (DIRS 180713-LVCVA 2006, all).

Hundreds of new jobs are added to the regional economy each month, and many job seekers have come to the area (primarily Clark County). Clark County has maintained a low unemployment rate near state and national averages. In January 2007, Clark County and Nye County had unemployment rates of 4.7 and 6.9 percent, respectively. The average in the State of Nevada was about 4.9 percent; the nationwide unemployment rate for the same period was about 4.6 percent (DIRS 180734-NDETR 2007, all).

In March 2005, an average of about 2,200 workers (210 on the site and 2,000 off) worked on the Yucca Mountain Project. By early 2007, the average number of onsite workers had fallen to fewer than 50. Most offsite workers, those primarily involved with engineering, licensing, project support, safety analysis, and related project support functions, worked in the Las Vegas area (DIRS 180788-BSC 2005, p. 3-12).

As would be expected, projected employment in the region of influence broadly reflects population trends. The number of jobs in Clark County is expected to reach approximately 2.2 million in 2067 (DIRS 178610, Bland 2007, all), up from 1.1 million in 2005. Clark County will host 98 percent of the employment opportunities in the region of influence. Nye County will add approximately 20,000 additional jobs by 2067 to the base of 17,000 in 2005 (DIRS 178610, Bland 2007, all).

In 2006, Clark County had 19 employers that maintained a payroll with at least 3,500 workers; the Clark County School District led with 30,000 to 39,999 workers, and the Clark County government was second with 10,000 to 19,999 workers. Many casinos in the county employed more than 3,500 workers. Private sector Bechtel Nevada Corporation led employers in Nye County with 1,000 to 1,499 workers, Nye County School District employed 900 to 999, and Round Mountain Gold Corporation employed at least 700 workers (DIRS 181180-NDETR 2006, all).

The 2005 per-capita income in Clark County was approximately $34,980, which is near the state's average of about $35,744. The per-capita income in Nye County was $28,761 (DIRS 180951-BEA 2007, all). The United States average per-capita income for the same period was $34,471 (DIRS 180952-BEA 2007, all).

3.1.7.3 Payments-Equal-to-Taxes Provision

An issue of interest is the DOE Payments-Equal-to-Taxes specified by the *Nuclear Waste Policy Act*, as amended (NWPA) (42 U.S.C. 10101 et seq.). DOE acquired data from the Yucca Mountain Project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include federal agencies, national laboratories, and private firms. Not all of them have a federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the project organizations that exercise a federal exemption are subject to the Payments-Equal-To-Taxes provision (DIRS 156763-YMP 2001, all).

DOE makes Payments-Equal-to-Taxes currently to the State of Nevada, Nye County, and Clark County. The amount paid to the state and to Clark County is formula-driven, but DOE and Nye County periodically negotiate (DIRS 181181-TischlerBise 2005, all) (Table 3-12). In Nye County, Payments-Equal-to-Taxes from the Yucca Mountain Project are currently a major revenue source for the county. These payments do not automatically increase with growth.

Table 3-12. DOE payments-equal-to-taxes for the Yucca Mountain Project, 2004 through 2007 (in dollars).

Jurisdiction	2004	2005	2006	2007	Total
State of Nevada	860,000	960,000	743,000	718,000	3,281,000
Nye County	10,250,000	10,500,000	10,750,000	11,000,000	42,500,000
Clark County	152,000	134,000	122,000	65,000	473,000
Total	11,262,000	11,594,000	11,615,000	11,783,000	46,254,000

Source: DIRS 181001-Lupton 2007, all.

3.1.7.4 Housing

As in much of the nation, the sale of new and existing homes in the Las Vegas area slowed in early 2007 and prices dropped. The greater Las Vegas area is expected to experience a decline in home prices of almost 9 percent in the next year (DIRS 180999-*Money* 2007, all). New home sales were down 44 percent in the first quarter of 2007 in comparison with the first quarter of 2006 (DIRS 181013-SNHBA 2007, all).

The housing inventory in Clark County in 2005 was about 720,000 units, which consisted of 440,000 single-family units, 240,000 multifamily units, and 35,000 mobile homes or other units. The occupancy rate was 89 percent during 2005. The average household size was 2.7 persons (DIRS 180738-Bureau of the Census n.d, all). The median value of a Clark County house or condominium in 2005 was $289,000, up from $140,000 in 2000. The median value of a house or condominium in the State of Nevada was nearly the same in 2005, $283,000.

In 2006, 36,000 new homes and 42,000 existing homes were sold (DIRS 180955-Smith 2007, all). In 2006, the median price of a new home was about $330,000, and the median price of an existing home was about $290,000 (DIRS 181013-SNHBA 2007, all). These sale prices are above the national median prices of $250,000 and $220,000 for new and existing homes, respectively (DIRS 181014-NAHB 2007, all).

The housing inventory in Nye County in 2000 was about 16,000 units, which consisted of 6,400 single-family units, 1,000 multifamily units, and 8,500 mobile homes or other units. The occupancy rate was 84 percent during 2000. The median value of houses and condominiums was about $122,100, or about 88 percent of the median value of a house in Clark County. Median rents in Nye County were $541 per month, about 76 percent of the median rent in Clark County. The average household size was 2.4 persons. The 2000 housing inventory in Pahrump was about 12,000 housing units of which 5,000 were single-family units, 6,200 were multifamily units, and 480 were mobile homes or other units (DIRS 181016-City-Data 2007, all). Nye County is expected to be attractive to home buyers because it is within commuting distance to metropolitan Las Vegas and has less expensive housing. Pahrump should be attractive to new workers because of its proximity to the Yucca Mountain site. The 2005 median value of a house or condominium in Pahrump was $117,000 (DIRS 181016-City-Data 2007, all). New home prices in Nye County continue to escalate as build-to-suit land with water rights becomes increasingly scarce. Although unincorporated, Pahrump is in the Pahrump Regional Planning District, which has adopted a land use plan and zoning regulations to guide future development. However, existing *infrastructure* systems are strained and inadequate. Rental unit vacancy rates are approaching zero.

Nye County purchased almost 61 acres near the current Gate 510 access road to the Nevada Test Site from the Bureau of Land Management to develop a science and technology business park. The park is the first phase of a proposed master development that will encourage a live-work community lifestyle in the town of Amargosa Valley.

The Pahrump Regional Planning District, which includes Nye County, Pahrump, and portions of the Nye County School District, has determined that the county's current revenue structure cannot adequately provide the current level of services to current residents. Current assessments on residential land uses are not paying their way and generate net deficits to the county. New residents would cause additional net deficits under the existing revenue structure (DIRS 181181-TischlerBise 2005, all).

3.1.7.5 Public Services

3.1.7.5.1 *Education*

In the 2005–2006 school year, the region of influence comprised approximately 270 public elementary and middle schools, 46 public high schools, and 31 alternative and special education schools (DIRS 181156-MGT 2006, p. 11-3; DIRS 181158-NDE n.d., all; DIRS 181159-NDE n.d., all). The Clark County School District expects to build about 180 new schools by 2018 to accommodate population growth (DIRS 181156-MGT 2006, p. 5-10). The average pupil-to-teacher ratio in the 2005–2006 school year was about 26 to 1 in kindergarten and 22 to 1 in all grades first to eighth; the national pupil-to-teacher ratio was about 19 to 1 for elementary schools and 15 to 1 for secondary schools (DIRS 181160-NDE n.d., all). During the 2005–2006 school year, Clark County had about 320 schools and nearly 294,000 students (Table 3-13). Enrollment in Clark County schools tends to be very large, with several high schools serving more than 3,000 students each. During the same period, Nye County had approximately 6,200 students in 17 schools spread over about 47,000 square kilometers (18,000 square miles), which vary in size from an enrollment of 10 students in Duckwater Elementary school to nearly 1,300 students in Pahrump High School (DIRS 181161-NDE n.d., all). Nye County school officials

Table 3-13. Enrollment by school district and grade level, for the 1996–1997 through 2005–2006 school years.

Jurisdiction	1996–1997[a,b]	2000–2001[a,c]	2005–2006[d]
Clark County			
Prekindergarten	1,100	1,100	1,880
Kindergarten	15,000	19,000	22,343
Elementary (grades 1 to 6)	90,000	120,000	141,429
Secondary (grades 7 to 12)	73,000	94,000	127,943
District totals[e]	179,000	232,000	293,961[f]
Nye County			
Prekindergarten	43	54	101
Kindergarten	370	360	403
Elementary (grades 1 to 6)	2,300	2,500	2,849
Secondary (grades 7 to 12)	2,200	2,300	2,870
District totals[e]	4,970	5,290	6,223[f]

a. Enrollment numbers by category rounded to two significant figures and district totals rounded to three significant figures for the 1996–1997 and 2000–2001 school years.
b. Source: DIRS 157146-NDE 2001, all.
c. Source: DIRS 155820-NDE 2001, all.
d. Source: DIRS 181169-NDE 2007, all.
e. Totals might differ from sums due to rounding.
f. Figures include students in ungraded situations.

report that all schools in the county are at capacity and that those in Pahrump exceed design capacity. A new elementary school is scheduled to open in fall 2008, and a new high school within 2 years of that in Pahrump. The balance of the county has opted to use modular units to accommodate the growth (DIRS 181182-Nye County School District 2007, all).

3.1.7.5.2 *Health Care*

Most health care services in the region of influence are in Clark County, particularly in the Las Vegas area. In January 2007, Clark County had 13 accredited general medical and surgical hospitals (DIRS 181162-AHA 2006, all) and several specialized care facilities. Several major health care providers have proposed new hospitals or expansions of existing facilities and are awaiting various governmental approval processes. Although Nye County has one unaffiliated (that is, with the American Hospital Association or Joint Commission on Accreditation of Healthcare Organizations) accredited hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in metropolitan Las Vegas. The very recently opened 24-bed critical care Desert View Medical Center in Pahrump has emergency room service available 24 hours a day, 7 days a week (DIRS 181162-AHA 2006, all). Table 3-14 lists hospital use in the region of influence.

Medical services are available at the Nevada Test Site for Yucca Mountain Project personnel; Section 3.1.7.5 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 3-92) describes these services.

3.1.7.5.3 *Law Enforcement*

The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County, with the exceptions of the cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in

Table 3-14. Hospital use by county in the region of influence, 1995 to 2006.

Jurisdiction	1995[a]	2000[b]	2006[c]
Clark County			
Population	1,000,000	1,380,000	1,900,000
Average number of beds	2,100	2,600	3,100
Beds per 1,000 residents	2.2	1.9	1.6
Patients days	530,000	NA	NA
Nye County			
Population	24,000	32,000	43,600
Average number of beds	21	42	44[d]
Beds per 1,000 residents	0.86	1.3	1.0
Patients days	1900	NA	NA

a. Source: DIRS 103451-Rodefer et al. n.d., pp. 214 to 216.
b. Source: DIRS 155872-Bureau of the Census 2000, County totals.
c. Source: DIRS 181162-AHA 2006, all.
d. Does not include the 24-bed Desert View Hospital, which opened in April 2006.
NA = Not available.

the 2004 to 2005 reporting period, the department had approximately 3,400 employees, including 2,250 commissioned officers—a ratio of 1.7 commissioned officers per 1,000 residents (DIRS 181163-LVMPD n.d., all). In 2005, the Nye County Sheriff's office had 141 employees, including 102 commissioned officers—a ratio of 2.5 commissioned officers per 1,000 residents. In comparison, the national officer-to-population ratio is 3.0 commissioned officers per 1,000 residents (DIRS 181167-FBI 2005, all; DIRS 181168-FBI 2005, all).

3.1.7.5.4 *Fire Protection*

A combination of fire departments that use career, part-time, and volunteer personnel provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. No single state or national agency gathers and categorizes information about fire suppression activities, services, and personnel in the region of influence. In January 2007, the Clark County Fire Department had about 685 paid and 350 volunteer firefighters (DIRS 181170-CCFD 2006, all). The department responded to about 111,000 incidents in 2006 from 20 stations (DIRS 181186-Nevada State Fire Marshal 2007, all). The Las Vegas Fire Department had about 560 employees reported in 2005 (DIRS 181647-Fire Departments Net 2005, all). The department responded to about 78,500 calls in 2006 (DIRS 181186-Nevada State Fire Marshal 2007, all) from 16 stations (DIRS 181646-CCFD 2005, all). In January 2006, the North Las Vegas Fire Department had 147 employees (DIRS 181171-Las Vegas Sun 2006, all) and answered 20,100 calls from seven stations (DIRS 181646-CCFD 2005, all). The Henderson Fire Department responded to 21,500 calls (DIRS 181186-Nevada State Fire Marshal 2007, all) from nine stations (DIRS 181646-CCFD 2005, all). Information for the Boulder City Fire Department was not available. The national average is 3.8 firefighters (paid and volunteer) per 1,000 residents (DIRS 181176-NFPA 2005, all).

In 2007, Nye County met fire suppression needs primarily with volunteers from the communities in the county. The Pahrump Valley Fire Department has career, part-time, and volunteer personnel. The department answered 155 calls in 2006 (DIRS 181186-Nevada State Fire Marshal 2007, all). The Nevada Test Site reported 26 fire calls. None of the eight all-volunteer departments reported calls to the State Fire Marshall in 2006, although the Nye County Fire Protection District Department responded to 31 calls. Nye County is hampered by its rural nature and size; assistance from mutual aid departments is often an hour away. Many conventional developed neighborhoods in the county lack fire hydrants. Most of the Town of Pahrump is outside the nationally recommended radius of 5 kilometers (3 miles) to achieve a 4- to 5-minute response time (DIRS 181184- Pahrump Valley Fire Rescue Service 2004, p. 6). DOE did not determine conventional resident-to-firefighter ratios because the large geographical area of the two counties distorts meaningful mutual aid and response time comparisons.

3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of members of the public who reside within an 80-kilometer (50-mile) radius of the geologic repository operations area. The region of influence includes parts of Nye, Clark, Lincoln, and Esmeralda counties in Nevada and Inyo County in California. DOE estimated the baseline population in this area in 2003 as 33,000 (DIRS 181663-Morton 2007, all); the population is mostly in small communities in the southern and western portions of the 80-kilometer radius (Figure 3-16). The baselines in this Repository SEIS incorporate population estimates and projections from the Nevada State Demographer's Office and the Center for Business and Economic Research at the University of Nevada, Las Vegas. The occupational health and safety region of influence includes workers at the repository and potentially affected workers at nearby Nevada Test Site facilities. This section summarizes, incorporates by reference, and updates Section 3.1.8 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-93 to 3-101).

3.1.8.1 Radiation Sources in the Environment

Radiation levels from background sources in the environment provide a basis for comparison with radiation from manmade sources. Background radiation derives from cosmic and cosmogenic sources, external terrestrial sources, radon in homes, and internally deposited radionuclides. The Yucca Mountain FEIS contains more detail about types of radiation.

The effect of radiation on people depends on the kind of radiation exposure (*alpha* and *beta particles*, and *x-rays* and *gamma rays*), the total amount of exposed tissue, and the duration of the exposure. The representative annual external doses for the region of influence range from a low of about 100 millirem at the town of Amargosa Valley to a high of 150 millirem at Beatty from terrestrial sources and cosmic and cosmogenic radiation. Internally deposited radionuclides contribute an additional 40 millirem per year, mainly from potassium-40, and doses from radon and its short-lived progeny add another 200 millirem per year. Therefore, the total dose from all background sources in the region of influence ranges from 340 to 390 millirem per year. This background dose varies by location and is slightly higher than the U.S. average, which is about 300 millirem per year.

Radiation can cause a variety of adverse health effects in people. The following discussion is an overview of a common method for estimation of the effects of radiation exposure; Appendix D of this Repository SEIS contains more detailed information. At low doses, the most important adverse health effect for estimation of the consequences of environmental and occupational radiation exposures (which typically are low) is the potential inducement of *cancers* that can lead to death in later years. This effect is referred to as a latent because the cancer might not be the cause of death and because cancer can take years to develop.

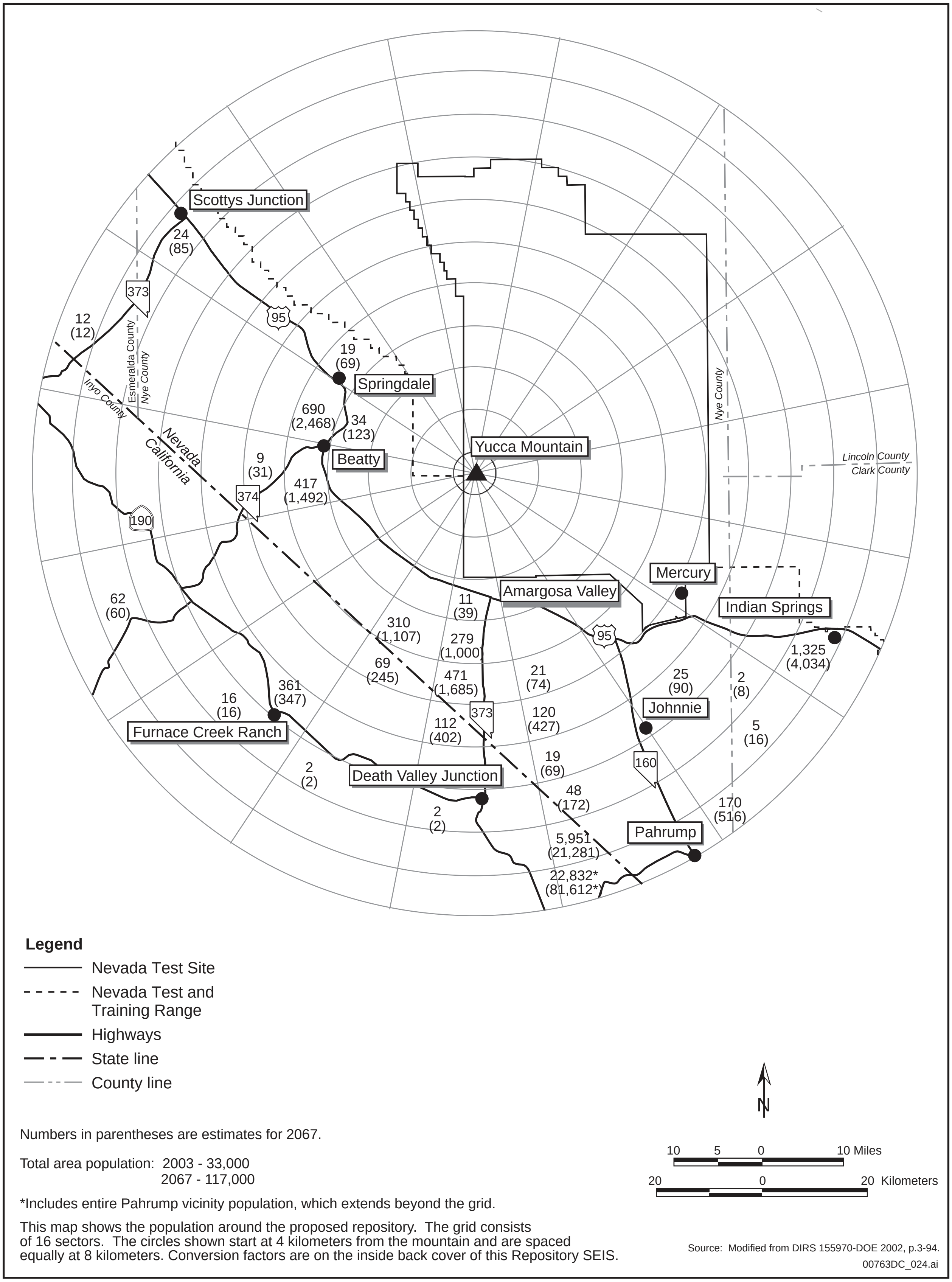

Figure 3-16. Population distribution within 80 kilometers of the proposed repository, 2003 estimations (2067 projections).

TERMS USED IN RADIATION DOSE ASSESSMENT

Curie: A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 *curie* of radioactivity.

***Picocurie per liter (or gram)*:** A unit of concentration measure that describes the amount of radioactivity (in picocuries) in volume (or mass) of a given substance [typically, air or water (by volume) or soil (by mass)]. A picocurie is one-trillionth of a curie.

Rad: A unit of absorbed radiation dose in terms of energy. One rad equals 100 ergs of energy absorbed per gram of tissue. (The word derives from *radiation absorbed dose*.)

Rem: The unit of effective *dose equivalent* from ionizing radiation to the human body. It is an expression of the amount of radiation to which a person has been exposed. The effective dose equivalent in rem is equal to the absorbed dose in rad multiplied by quality and weighting factors that are necessary because biological effects can vary both by the type of radiation (even of the same deposited energy) and by the specific tissue exposed. (The word derives from *roentgen equivalent in man*.

Millirem: One one-thousandth (0.001) of a rem.

***Total effective dose equivalent*:** Often generically referred to simply as dose, it is an expression of the radiation dose received by an individual from external radiation and from radionuclides internally deposited in the body. All doses presented in this Repository SEIS are in terms of total effective dose.

Latent cancer fatality: A death that results from cancer that exposure to ionizing radiation caused. There typically is a latent period between the time of the radiation exposure and the time the cancer cells become active.

Solid cancer: *Solid cancers* include all malignant neoplasms other than those of the lymphatic and hematopoietic tissue (DIRS 181250-National Research Council 2006, p. 377).

The collective dose to an exposed population is the sum of the estimated doses to each member of the exposed population. This is referred to as a *population dose*, which is measured in *person-rem*. For example, if 1,000 people each received a dose of 0.001 *rem*, the population dose would be 1 person-rem (1,000 persons multiplied by 0.001 rem equals 1 person-rem). The same population dose (1 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

As recommended by the Interagency Steering Committee on Radiation Standards, this Repository SEIS uses a conversion factor of 0.0006 *latent cancer fatality* per person-rem, for both workers and the public, to estimate the radiological impacts of repository operations (DIRS 174559-Lawrence 2002, p. 2). The factor is higher than those the Yucca Mountain FEIS used, which were 0.0004 and 0.0005 latent cancer fatality per person-rem for workers and the public, respectively (DIRS 155970-DOE 2002, p. 3-97).

As stated in the Yucca Mountain FEIS, these concepts can be used to estimate the effects of exposure to radiation. For example, if 100,000 people each were exposed only to background radiation (0.3 rem per year), an estimated 18 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0006 latent cancer fatality per person-rem equals 18 latent cancer fatalities).

Calculations of the number of latent cancer fatalities due to radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1. For example, if 100,000 people each were exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.06 (100,000 persons multiplied by 0.001 rem multiplied by 0.0006 latent cancer fatality per person-rem equals 0.06 latent cancer fatality).

The estimated average number of deaths that could result if many different groups of 100,000 people received the same exposure is 0.06. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose each member received. In a small fraction of the groups, 1 latent cancer fatality would result; in exceptionally few groups, 2 or more latent cancer fatalities would occur. The average number of deaths over all the groups would be 0.06 latent cancer fatality per 100,000 (just as the average of 0, 0, 0, and 1 is 0.25). The most likely outcome is no latent cancer fatalities in any of the different groups.

To aid in decisionmaking, DOE has applied these same concepts to estimate the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The probability of a latent cancer fatality that corresponds to a single individual's exposure to 0.3 rem per year over a (presumed) 70-year lifetime is:

$$\begin{aligned}\text{Probability of a latent cancer fatality} &= 1 \text{ person} \times 0.3 \text{ rem per year} \times 70 \text{ years} \\ &\quad \times 0.0006 \text{ latent cancer fatality per person-rem} \\ &= 0.013 \text{ probability of a latent cancer fatality}\end{aligned}$$

This is a statistical average; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.3-percent chance that the individual would incur a latent cancer fatality. For comparison purposes, statistics from the Centers for Disease Control and Prevention indicate that 24 percent of all deaths in the State of Nevada during 1998 were attributable to cancer from all causes (DIRS 153066-Murphy 2000, p. 83).

3.1.8.2 Radiation Environment at the Yucca Mountain Repository

Environmental radiation at the Yucca Mountain Repository consists of natural background radiation from cosmic and terrestrial sources, past nuclear testing activities, and radon releases from activities at the Exploratory Studies Facility. The Yucca Mountain FEIS detailed the radiation exposure rates from these sources and the existing radiological environments in the region of influence. Table 3-15 summarizes major radiation sources and associated doses.

3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain. The risks generally are related to potential exposure caused by inhalation of airborne particulates (dust). These minerals include crystalline silica (silica dioxide) and erionite and have been determined by the International Agency for Research on Cancer to be known human *carcinogens*. The National Institute of Health, U.S. Department of Human Services, has included silica and erionite on its list of "Known to be Human Carcinogens" report that was provided to Congress (DIRS 176678-DOE 2006, p. 6-12). Crystalline silica comes in several forms that include quartz, tridymite, and cristobalite. Prolonged exposure to silica dust can result in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity. DOE performs evaluations of airborne crystalline silica at Yucca Mountain during routine operations and tunneling. The repository host rock has cristobalite content that ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). The American Conference

Table 3-15. Major sources of radiation exposure at Yucca Mountain.

Sources of exposure	Dose rate (per year)
Natural background radiation	
Cosmic and terrestrial radiation at Yucca Mountain ridge	160 millirem
ESF operations	
Median external dose rate to ESF workers	40 millirem
Average inhalation dose rate to ESF workers from radon and decay products	40 millirem
Annual dose to an individual 20 kilometers south of the ESF from exposure to ESF radon releases	<0.1 millirem
Annual dose to the population within 80 kilometers of the repository from exposure to ESF radon releases	10 person-rem
Radiation doses from past nuclear testing activities at Nevada Test Site	
Maximum annual dose to an individual in Springdale, Nevada, 14 kilometers north of Beatty	0.12 millirem
Annual dose to the population within 80 kilometers of the Nevada Test Site	0.38 person-rem

Source: DIRS 155970-DOE 2002, pp. 3-98 to 3-100.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
ESF = Exploratory Studies Facility.

of Governmental Industrial Hygienists has established *threshold limit values* for various forms of crystalline silica. Further, crystalline silica has been listed by the World Health Organization as a carcinogen.

Underground mechanical excavation produces dust when the rock is broken loose. Dust is also generated when the broken rock is transferred to railcars, conveyors, or a storage pile, and can also be generated by wind erosion of excavated rock storage piles. Excavation activities during past activities at Yucca Mountain have resulted in some exceedences of crystalline silica threshold limit values at specific work locations. In these cases, workers at these locations are required to wear respirators to mitigate occupational exposures.

Erionite is an uncommon zeolite mineral that forms wool-like fibrous masses. The International Agency for Research on Cancer recognized erionite as a human carcinogen in 1987 (DIRS 103278-IARC 1987, all). Even at low concentrations, erionite is believed to be a potent carcinogen, capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite may pose a risk if encountered in quantity during underground construction. However, based upon geologic studies to characterize the repository horizon, erionite appears to be absent or rare at the proposed repository depth and location, so most operations have not been affected. During excavation activities, continuous monitoring of the geologic strata is performed. Should erionite be encountered, the area is sealed off and remediated. During the initial tunneling operations in the mid 1990s, one vein of erionite was encountered. This vein was only a few millimeters in width and was found in the far south region of the exhaust tunnel and not in the main repository horizon. In subsequent studies, only minor traces of erionite have been found in the repository horizon (DIRS 176678-DOE 2006, p. 6-12).

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur. These minerals include the zeolite group minerals mordenite (which is fibrous), clinoptilolite, heulandite, and phillipsite. Even though these are not classified as known human carcinogens, the measures implemented to mitigate occupational risk from silica (including dust suppression, air filters, and personal-protective gear) also protect workers from exposure to other minerals.

In January 2004, DOE announced a Silicosis Medical Screening Program for Yucca Mountain tunnel workers who were involved in tunneling and underground operations between 1992 and 2004. The DOE Office of Civilian Radioactive Waste Management and the University of Cincinnati mailed 6,228 informative letters, postcards, and invitations to affected individuals to participate in the screening program. A total of 978 persons responded to the mailings, 551 of them completed a work history interview, and 414 of those interviewed underwent a medical examination. The final report from the University of Cincinnati diagnosed two cases of silicosis. Both cases were found in the screening examination, although one case previously had been diagnosed and reported as medical history. These cases of silicosis cannot be attributed solely to exposure at Yucca Mountain because both workers had a long history of working in occupations that were dusty and likely to contain silica dust. The average age of the two confirmed silicosis cases was 70 years, the average time working in mining or tunneling occupations was 30 years, and the average time working at Yucca Mountain was 5 years (DIRS 181251-OCRWM 2007, all). Compensation coverage for DOE employees exposed to silica is defined in the *Energy Employees Occupational Illness Compensation Program Act*, which is administered by the U.S. Department of Labor.

3.1.8.4 Industrial Health and Safety Impacts During Past Construction Activities

During past activities related to construction at Yucca Mountain, health and safety impacts to workers resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include *recordable incidents*, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death; (2) *lost workday cases* (nonfatal); and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

To date, activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity during which the tunnel boring machine was in operation in the Exploratory Studies Facility. Table 3-16 lists the industrial health and safety loss statistics for industry, general construction, general mining, and Yucca Mountain for the period during which the Exploratory Studies Facility was constructed. The table also lists current industrial health and safety loss statistics. DOE expects these statistics to be representative for the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts.

Table 3-16. Health and safety statistics for total industry, general construction, general mining, and Yucca Mountain, 1997 and 2005.[a]

Rates	Total industry	General construction	General mining	Yucca Mountain experience for involved workers
1997 total recordable cases	7.1[b]	9.5[b]	5.9[b]	6.8
2005 total recordable cases	4.6[c]	6.3[c]	4.1[c]	0
1997 lost workday cases	3.3[b]	4.4[b]	3.7[b]	4.8
2005 lost workday cases	2.4[c]	3.4[c]	2.7[c]	0

a. Based on 100 full-time equivalent worker years or 200,000 worker hours.
b. Data for 1997 for the period of excavation of the Exploratory Studies Facility (DIRS 148091-BLS 1998, all).
c. Data for 2005 (DIRS 179131-BLS 2006, all).

3.1.9 NOISE AND VIBRATION

The region of influence for noise and vibration includes the Yucca Mountain site and existing and future residences to the south in the town of Amargosa Valley. This section discusses the affected environment in terms of noise sources and levels, regulatory standards, and vibration, and it summarizes and incorporates by reference Section 3.1.9 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-101 to 3-104).

> **A-weighted decibels (dBA):** A measurement of sound that approximates the sensitivity of the human ear, which is used to characterize the intensity or loudness of sound.
>
> **Day-night average sound level:** The energy average of the A-weighted sound levels over a 24-hour period. It includes an adjustment factor for noise between 10 p.m. and 7 a.m. to account for the greater sensitivity of most people to noise during the night.
>
> **Vibration velocity decibels (VdB):** Vibration velocity in decibels with respect to 1 microinch per second. A measurement of root-mean-square velocity for the evaluation of ground vibration as an average or smoothed vibration amplitude on a logarithmic scale.

3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. Average day-night sound-level values range from 22 *A-weighted decibels (dBA)* on calm days to 38 dBA on windy days. Manmade noise levels at the Yucca Mountain Exploratory Studies Facility were consistent with noise levels near industrial operations, which range from 44 to 72 dBA. The nearest housing to Yucca Mountain is in the town of Amargosa Valley about 22 kilometers (14 miles) to the south. The estimated sound level in the town of Amargosa Valley ranges from 45 to 55 dBA.

3.1.9.2 Regulatory Standards

With the exception of prohibitions of nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many federal agencies use *day-night average sound levels* as guidelines for land use compatibility and to assess the impacts of noise on people. As required, DOE has a hearing protection program in place that includes monitoring of noise levels in worker areas. Engineering controls are the primary methods of noise suppression, and the plan requires supplemental hearing protection when noise levels exceed safe levels.

Sound levels that cause annoyance vary greatly by individual and background conditions. The threshold for hearing hazard, which depends on the frequency of the sound, ranges from around 65 *decibels* at a frequency of 4,000 hertz to about 88 decibels at 125 and 8,000 hertz. These threshold levels assume continuous exposure for periods of hours. High risk for hearing loss occurs at 120 dBA and can result from exposures as brief as seconds to minutes.

3.1.9.3 Vibration

Many natural phenomena such as wave action on beaches, strong winds, and earthquakes, as well as human activities such as construction, transportation, and military activities, cause ground vibration. Background vibration almost always exists to some degree, and levels are generally higher in large cities than in rural communities.

A typical background level of ground vibration is 52 *vibration velocity decibels* with respect to 1 microinch per second (VdB), and the human threshold for the perception of ground vibration is 65 VdB. There are three ground vibration impacts of general concern: human annoyance, damage to buildings, and interference with vibration-sensitive activities.

Background levels for ground vibration at the Yucca Mountain site are low. Other than site maintenance activities, there is a lack of the classic manmade sources of ground vibration.

3.1.10 AESTHETICS

Visual resources, with nighttime darkness as a component, include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The region of influence for aesthetics includes the approximate boundary of the analyzed land withdrawal area, an area west of the boundary where ventilation stacks could potentially be seen, and the area south of the boundary where DOE would construct the access road from U.S. Highway 95 and several offsite facilities. This section summarizes, incorporates by reference, and updates Section 3.1.10 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-104 to 3-106).

The Yucca Mountain region consists of unpopulated to sparsely populated desert and rural lands. Because much of Yucca Mountain is on the Nevada Test Site and the Nevada Test and Training Range, both with restricted public access, the public can see Yucca Mountain only from portions of U.S. Highway 95 near the intersection of State Route 373.

The Bureau of Land Management assigns visual resource values to lands that it manages. The Bureau classification of visual resource values involves assessment of visual resources and assignment of one of four visual resource management classes based on three factors: scenic quality, visual sensitivity, and distance from travel routes or observation points. Class I represents the highest visual values and Class IV represents the lowest. Each visual resource class has an associated management objective that defines permissible land uses and developments. Table 3-17 describes the Bureau of Land Management objectives for visual resource classes.

The Bureau of Land Management has classified a portion of the analyzed land withdrawal area, with characteristics fairly common to the region, as Class IV and the remainder as Class III. The land to the west of the site consists of Class III and Class IV lands. The lands south of the analyzed land withdrawal

Table 3-17. Bureau of Land Management visual resource management classes and objectives.

Visual resource class	Objective	Acceptable changes to land
Class I	Preserve the existing character of the landscape.	Provides for natural ecological changes but does not preclude limited management activity. Changes to the land must be small and must not attract attention.
Class II	Retain the existing character of the landscape.	Management activities may be seen but should not attract the attention of the casual observer. Changes must repeat the basic elements of form, line, color, and texture of the predominant natural features of the characteristic landscape.
Class III	Partially retain the existing character of the landscape.	Management activities may attract attention but may not dominate the view of the casual observer. Changes should repeat the basic elements in the predominant natural features of the characteristic landscape.
Class IV	Provides for management activities that require major modifications of the existing character of the landscape.	Management activities may dominate the view and be the major focus of viewer attention. An attempt should be made to minimize the impact of activities through location, minimal disturbance, and repeating the basic elements.

Source: DIRS 101505-BLM 1986, Section V.B.

area boundary, where DOE would construct the access road from U.S. Highway 95, the Marshalling Yard and Warehouse, Sample Management Facility, Offsite Training Facility, and temporary accommodations for construction workers, are Class III. Land on the Nevada Test Site is not under Bureau of Land Management jurisdiction but, using the Bureau's methods, DOE has assigned these lands as Class IV. Figure 3-17 shows the visual resource classifications.

Nighttime darkness in the Yucca Mountain region is a valued component of the solitude experience many people seek and greatly enhances astronomy and stargazing activities. Existing or potential sources of nighttime light in this area include the towns of Beatty and Amargosa Valley between Death Valley National Park and the Yucca Mountain site, the community of Pahrump slightly east of the park, and particularly Las Vegas farther to the east. Current lighting at the Yucca Mountain site is similar to or less than lighting at other work areas on the Nevada Test Site and represents a minor contribution to the area's sources of nighttime lighting.

3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

The region of influence for potential impacts to utilities, energy supplies, and site services comprises those public and private resources on which DOE would draw to support the Proposed Action. These resources are in Nye, Clark, and Lincoln counties in Nevada. Utilities include water and sewer services, energy supplies include electric power and fossil fuel, and site services include security, medical, and fire protection. This section summarizes, incorporates by reference, and updates Section 3.1.11 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-106 to 3-110) and presents new information DOE has accumulated since it completed the FEIS.

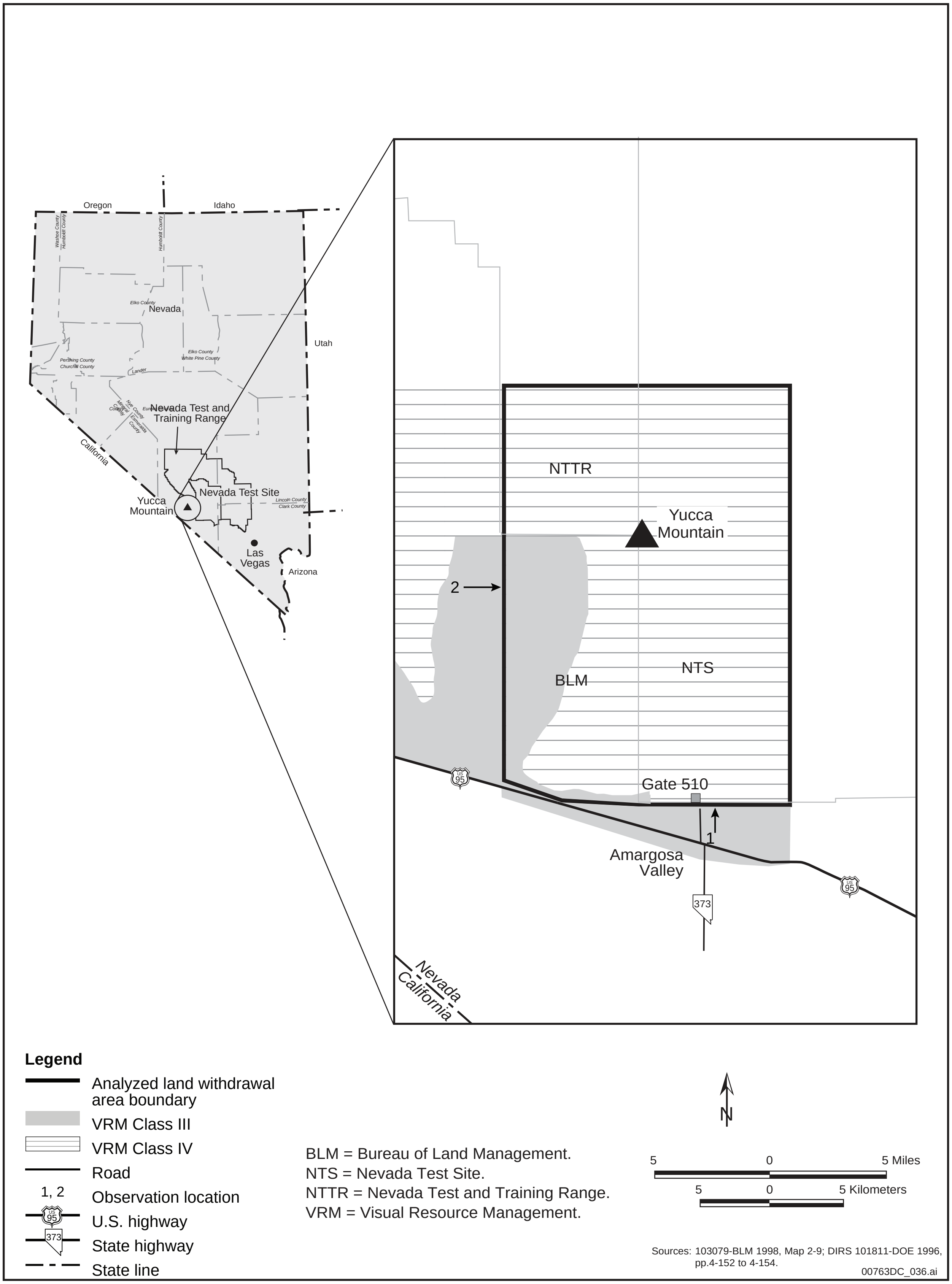

Figure 3-17. Visual Resource Management classifications in the region of influence.

3.1.11.1 Utilities

The Proposed Action could affect water and sewer utilities through project-related increases in population and the associated increases in water demand and sewage production. Based on historical residency patterns, DOE anticipates that the majority of project-related increases in population would occur in Clark and Nye counties (DIRS 155970-DOE 2002, p. 3-82).

3.1.11.1.1 *Water*

The Southern Nevada Water Authority is a cooperative agency that was formed in 1991 to address southern Nevada's regional water needs. It is the wholesale water provider to municipal water agencies in the Las Vegas Valley and Boulder City. It supplies water to the communities of Boulder City, Henderson, Las Vegas, North Las Vegas, Laughlin, and portions of unincorporated Clark County (DIRS 181261-SNWA n.d., p. v). Southern Nevada gets nearly 90 percent of its water supply from the Colorado River and the remaining 10 percent from groundwater. To meet growing water demands, the Southern Nevada Water Authority is upgrading current facilities as well as installing new facilities. In 2002, the Authority completed a second water intake system at Lake Mead; and it has scheduled a third for completion in 2011. The Southern Nevada Water Authority is identifying new water resources and developing a portfolio of resource options to help meet potential future demands. The portfolio includes both Colorado River water options (such as apportionments, water banks, and water exchanges) and in-state, non-Colorado River water options (such as Las Vegas Valley groundwater rights, shallow groundwater, surface-water rights, and groundwater rights in other portions of Clark County as well as Lincoln, White Pine, and Nye counties) (DIRS 181261-SNWA n.d., pp. v and vi).

In southern Nye County, the location of the proposed repository, groundwater is the only source of water. Total groundwater use in Nye County in 2000 was approximately 125 million cubic meters (101,000 acre-feet) (DIRS 173226-Buqo 2004, p. 47). Historically, nearly 80 percent of Nye County's annual groundwater withdrawal is for agricultural irrigation and only 7 percent is for domestic purposes (including public supplies). Mining uses an additional 9 percent, public use and losses use 2 percent, livestock use 1 percent, and commercial activities use 1 percent (DIRS 173226-Buqo 2004, p. 41).

Since completion of the Yucca Mountain FEIS, a new water supply and demand evaluation has become available for Nye County (DIRS 173226-Buqo 2004, all). The evaluation indicated that Beatty (Oasis Valley Hydrographic Area) has adequate water rights and wells to meet projected future demands. A water connection moratorium that was in effect in 1996 ended after another well (the former Barrick Gold Well EW-4) was brought online. The only significant water issues in Beatty are the naturally occurring levels of arsenic and fluoride in the groundwater and the water treatment that could be necessary to reduce those levels (DIRS 173226-Buqo 2004, p. 85). In the Amargosa Desert Hydrographic Area, the existing groundwater rights of 35 million cubic meters (28,600 acre-feet) exceed the published perennial yield of 30 million cubic meters (24,000 acre-feet). However, actual water use in the basin is far less and has not yet exceeded 20 million cubic meters (16,000 acre-feet). Existing groundwater sources would be adequate for anticipated needs (DIRS 173226-Buqo 2004, pp. 80 to 83). Although activities at Yucca Mountain would not require the use of water from the Pahrump Valley Hydrographic Area, project-related population increases could cause increased water use in the hydrographic area. The total groundwater that was pumped from the Pahrump Valley Hydrographic Area in 2000 was about 28 million cubic meters (23,000 acre-feet), which was the lowest demand since 1993 because of a decrease in water being pumped for irrigation. This is about 21 percent higher than the upper end of estimates of the perennial yield of that hydrographic area, which ranges from 15 million to 23 million cubic meters (12,000 to 19,000 acre-feet). Water consumption in the Pahrump Valley results from approximately 8,700 domestic water wells; nearly 300 irrigation wells; and 254 municipal, commercial, and industrial wells (DIRS 173226-Buqo 2004, p. 89). Drilling continues at a rate of over 400 wells a year. With projected population increases, the annual demand for water could be about 99 million cubic meters (80,000 acre-feet) by 2050 (DIRS 173226-Buqo 2004, p. 95). Possible alternatives for meeting the projected future water shortfalls in the Pahrump Valley include a managed overdraft of the basin by optimizing the locations of new wells, development of the carbonate aquifer that underlies the basin, importation of water from other basins, and administrative actions such as conservation (DIRS 173226-Buqo 2004, pp. 57 to 59). In 2007, the Nevada Legislature passed a measure enacting the Nye County Water District. The District is empowered to manage water within the boundaries of Nye County in a manner similar to that of the Southern Nevada Water Authority in Clark County.

3.1.11.1.2 *Sewer*

Wastewater treatment in the Las Vegas Valley occurs in facilities of the City of Las Vegas (which also serves the City of North Las Vegas), Boulder City, Henderson, and the Clark County Water Reclamation District (DIRS 181261-SNWA n.d., p. v). The District serves portions of unincorporated Clark County and the communities of Blue Diamond, Indian Springs, Laughlin, Overton, and Searchlight (DIRS 181264-CCWRD n.d., all). Although other small wastewater treatment facilities might service parts of Clark County outside the populous areas of the Las Vegas Valley, septic systems provide the primary means of treatment in these outlying areas, particularly for private residences.

Most communities in southern Nye County rely primarily on septic systems or small communal wastewater treatment systems, with the exception of Beatty, which has municipal sewer service. Pahrump has no community-wide wastewater treatment system, although the formation of a sanitary district in the Pahrump area has been investigated to provide an area-wide solution for sanitary sewer service (DIRS 181265-Tri-Core Engineering 2005, all). Nye County is developing a service plan for the Pahrump Regional Planning District, which is the first required step in the formation of a sanitary sewer district.

3.1.11.2 Energy

3.1.11.2.1 *Electric Power*

The Yucca Mountain FEIS described the distributors that supply electric power in the region of influence: Nevada Power Company, Valley Electric Association, and Lincoln County Power District No. 1.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County that includes Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. The power sources were approximately 39 percent company-generated and 61 percent purchased power in 2005. In 2005, Nevada Power Company sold 21 million megawatt-hours to its 770,000 customers, and the peak load was the highest ever at just under 5,600 megawatts. The company has an annual customer growth rate of approximately 6 percent, the highest of any electric utility in the country (DIRS 172302-Nevada Power Company 2004, all). It forecasts a 1.8-percent average rate of growth in peak demand through 2020, when it should reach its highest anticipated level of about 7,500 megawatts (DIRS 173383-Nevada State Office of Energy 2005, p. 23). To keep pace with demands for electricity, Nevada Power Company must build more substations and transmission and distribution facilities each year. It added a 1,160-megawatt generating station and a 75-megawatt unit in early 2006 (DIRS 181270-Nevada Power Company 2006, all). The completion of several other projects, which include the first two phases of the Centennial project (a transmission line and substation construction project) and the ongoing construction at existing power plants, should ensure an adequate supply of electric power (DIRS 173383-Nevada State Office of Energy 2005, p. 34).

The Valley Electric Association distributes power to southern Nye County, which includes Pahrump, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric Association a portion of the lower-cost hydroelectric power from the Colorado River dams. However, the combination of increased demand and low water levels has decreased the hydroelectric power share to only 20 percent of Valley Electric Association's total electricity resources. The private market supplements power to meet the demands of association members. The costs of purchased power represent 62 percent of the total expenses of the cooperative. The amount of energy that Valley Electric Association sells annually to its members almost tripled in the 11 years from 1985 through 1995. The annual sales of energy increased by another 100 million kilowatt-hours between 1995 and 2005. In 2005, Valley Electric Association sold approximately 400 million kilowatt-hours to its 19,000 members. The association invested more than $4.3 million in 2005 in new plant facilities and system improvements to ensure continued reliable service to its members (DIRS 181273-VEA 2005, all).

Lincoln County Power District No. 1 is a general-improvement district with headquarters in Caselton, Nevada, that serves approximately 820 customers. It supplies more than 72,000 megawatt-hours per year (DIRS 173383-Nevada State Office of Energy 2005, p. 40).

The Nevada Test Site power grid provides transmission of electric power for ongoing operations at Yucca Mountain. At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-18). The description of the existing Test Site power supply incorporates by reference Section 3.1.11.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 108).

Table 3-18 lists the historical electricity use (partially estimated) for ongoing Yucca Mountain operations for 1995 through 2000. Annual power use and peak demand declined and stabilized at a level lower than the 1997 values due to the decline of site activity after 1997. From 1995 through 1997 Yucca Mountain ongoing operations accounted for about 15 to 20 percent of the electric power the Nevada Test Site used.

3.1.11.2.2 *Fossil Fuel*

Tanker trucks deliver fossil fuels (heating oil, propane, diesel, gasoline, and kerosene) to the Nevada Test Site and the Yucca Mountain site from readily available supplies in southern Nevada. Since 2002, when Congress and the President designated the site as suitable for a repository, consumption of fossil fuels by the Yucca Mountain Project has declined in step with the reduction in site characterization activities.

The fossil-fuel system in the region of influence, the State of Nevada, has sufficient capacity to meet normal Nevada demands. However, the *isolation* of Nevada cities and the limited number of pipelines that provide service to the state can make the system marginally reliable (DIRS 173383-Nevada State Office of Energy 2005, p. 69).

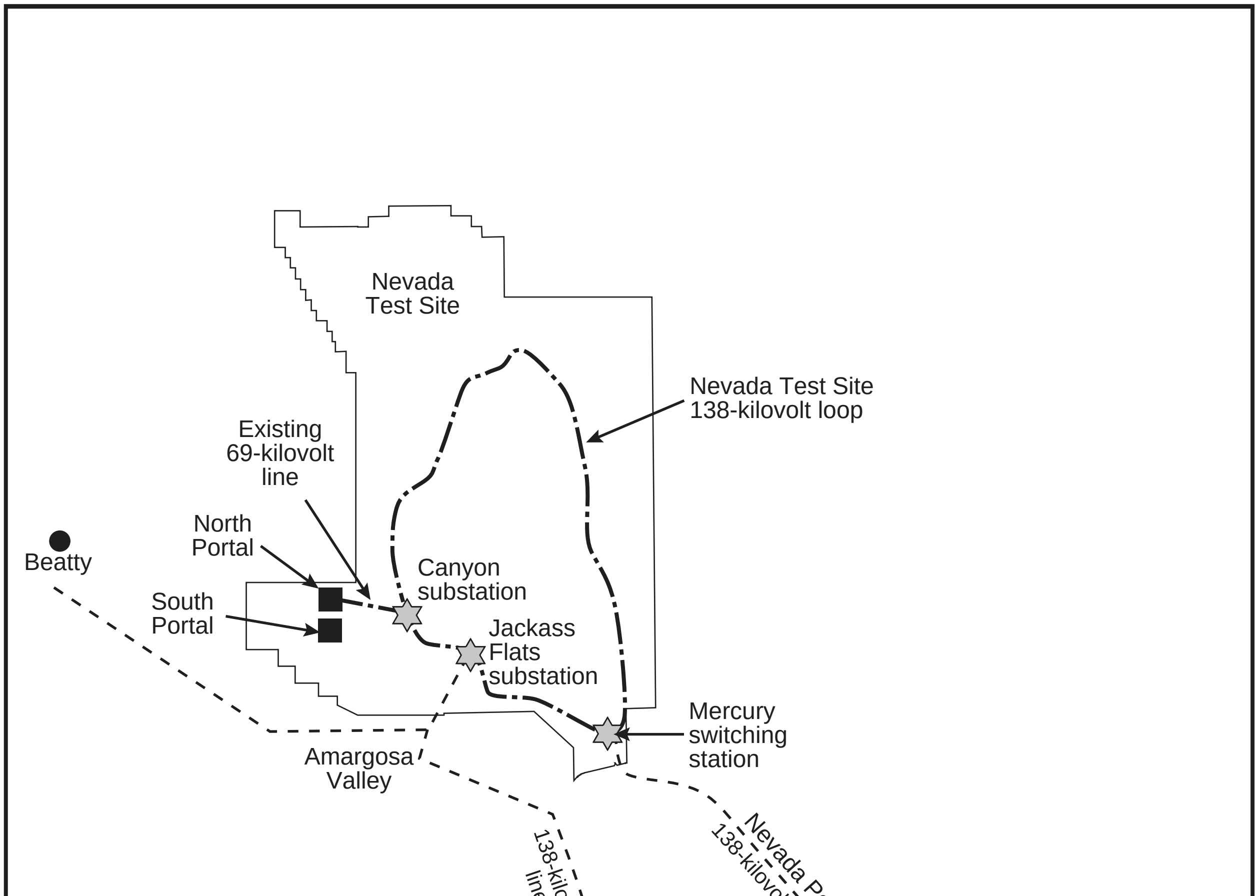

Figure 3-18. Existing Nevada Test Site electric power supply.

Table 3-18. Electric power use for the Exploratory Studies Facility and Field Operations Center.

Fiscal year[a]	Consumption (megawatt-hours)	Peak (megawatts)
1995	9,800	3.5
1996	19,000	4.9
1997	23,000	5.3
1998[b]	21,000b	4.2[b]
1999[b]	17,000[b]	4.2[b]
2000[b]	8,700[b]	4.2[b]

Source: DIRS 155970-DOE 2002, p. 108.
a. Before 1995, Yucca Mountain Project power was not separately metered.
b. Estimated.

3.1.11.3 Site Services

DOE has established a support infrastructure to provide emergency services to the Yucca Mountain Project. The *Yucca Mountain Project Emergency Management Plan* describes emergency planning, preparedness, and response (DIRS 167254-DOE 2003, all). The Yucca Mountain Project cooperates with the Nevada Test Site in such areas as training, emergency drills, and exercises to provide full emergency preparedness capability. In addition, the Yucca Mountain Project trains and maintains an underground rescue team. The Nevada Test Site provides support for the Yucca Mountain security program, fire protection, and medical services. The Nye County Sheriff's Department provides traffic enforcement and has authority for civil disturbances. The Yucca Mountain Project has access to a Flight for Life helicopter that can transport two victims to a trauma center in Las Vegas, Nevada.

3.1.12 WASTE AND HAZARDOUS MATERIALS

This section summarizes, incorporates by reference, and updates as appropriate Section 3.1.12 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-110 to 3-312). This section discusses changes in the plans for treatment and disposal of waste and the management of hazardous materials at the proposed repository since the completion of the Yucca Mountain FEIS, and it reevaluates the capacities of regional facilities that could receive waste from Yucca Mountain.

The region of influence for waste and hazardous materials consists of on- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of waste it generated under the Proposed Action. At present, the types of waste the Yucca Mountain Project generates are solid waste and construction debris, oil-contaminated debris, hazardous waste, sanitary sewage, and wastewater.

3.1.12.1 Solid Waste

DOE disposes of solid waste from the Yucca Mountain Project in landfills on the Nevada Test Site in Areas 23 and 9. Both landfill capacities and their estimated operational life spans have not changed since the completion of the Yucca Mountain FEIS. Although DOE currently disposes of solid waste at the Nevada Test Site, it could send such waste to other locations on the Test Site or in the land withdrawal area, or to nearby municipal solid waste landfills. In addition to the landfills on the Test Site, there are 23 operating municipal solid waste landfills including four *industrial waste* landfills in Nevada (DIRS 182603-NDEP 2007, all). Since 2002, the total capacity of landfills in Nevada has increased from

150 million cubic meters (200 million cubic yards) to 1.1 billion cubic meters (1.4 billion cubic yards). Although DOE could dispose of solid waste throughout the state, the landfills that would be the most likely receive waste from Yucca Mountain are those in Nye, Lincoln, Clark, and Esmeralda counties. Of those landfills, the Apex Regional landfill in Clark County is the largest municipal landfill and receives over half of the waste disposed of in Nevada, averaging over 10,000 metric tons (11,000 tons) of solid waste per day. Based on current waste disposal rates and remaining lifespan estimates from the Nevada Division of Environmental Protection, the Apex Regional landfill has a total of approximately 144 remaining life years left and a total capacity of about 661 million cubic meters (865 million cubic yards).

In addition, DOE transports recyclable materials from site maintenance activities off the site for recycling. Recyclable materials include paper, cardboard, aluminum cans, scrap metal, used oil, used antifreeze, and lead-acid batteries.

3.1.12.2 Hazardous Waste Disposal Facilities

HAZARDOUS WASTE

Waste designated as hazardous by EPA or State of Nevada regulations. Hazardous waste, defined under the *Resource Conservation and Recovery Act*, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special EPA lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

DOE currently contracts with permitted hazardous waste vendors to ship hazardous waste from the Yucca Mountain site to offsite treatment, storage, and disposal facilities that handle waste under the provisions of the *Resource Conservation and Recovery Act*, as amended (42 U.S.C. 6901 et seq.). Although commercial companies that collect hazardous waste for processing and disposal could use facilities throughout the country, DOE considered only the currently available hazardous waste facilities in the western United States. Estimates for the western states place the hazardous waste disposal capacity as high as 50 times the demand for landfills and seven times the demand for incineration until at least 2013. There are currently three hazardous waste treatment, storage, and disposal facilities in Nevada. The American Ecology Treatment and Disposal Site in the town of Beatty treats and disposes of hazardous wastes, nonhazardous industrial wastes, and wastes that contain polychlorinated biphenyls. Safety-Kleen Systems operates a hazardous waste treatment, storage, and disposal facility in North Las Vegas and Phillip Services Corporation operates a similar facility in the City of Fernley.

The Department sends recyclable hazardous wastes, such as solvents, corrosives, and fuels, to appropriate facilities for recycling.

3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site. The system design can handle a daily flow of about 76 cubic meters (20,000 gallons) (DIRS 102599-CRWMS M&O 1998, p. 64).

3.1.12.4 Existing Low-Level Radioactive Waste Disposal Facilities

> **AGREEMENT STATE**
>
> A state that reaches an agreement with the NRC to assume regulatory authority to license and regulate radioactive materials.

At present, the Yucca Mountain Project does not generate *low-level radioactive waste*, but it would during repository operations. This section describes only those facilities that currently receive low-level radioactive waste in the United States, but DOE has not committed to a disposal location for such waste. Low-level radioactive waste disposal occurs at a DOE low-level waste disposal site, sites in *Agreement States*, or NRC sites. The Nevada Test Site is one of the nation's approved sites for the disposal of low-level waste. Only DOE and U.S. Department of Defense generators may ship waste for disposal at the Test Site. The Radioactive Waste Acceptance Program at the Nevada Test Site ensures safe disposal operation by requiring waste generators to meet strict waste acceptance criteria before *shipment* and disposal (DIRS 181748-DOE 2006, all).

In addition to the Nevada Test Site, there are three existing commercial low-level radioactive waste disposal facilities in the United States: EnergySolutions Barnwell Operations in Barnwell, South Carolina; U.S. Ecology in Richland, Washington; and EnergySolutions Clive Operations in Clive, Utah. These facilities are in Agreement States and accept waste from all or parts of the nation. NRC evaluates Agreement State programs every 2 to 4 years to ensure consistency in the nation's materials and safety programs.

3.1.12.5 Materials Management

DOE has programs and procedures in place for the Yucca Mountain Project to procure and manage hazardous and nonhazardous materials (DIRS 104842-YMP 1996, all). By using these programs, DOE minimizes health and environmental hazards of hazardous materials at the Yucca Mountain site. DOE would continue the use of the programs throughout repository operations.

The *Nevada Combined Agency Hazardous Material Facility Report* (DIRS 181526-Spence 2007, all) from the Nevada State Fire Marshal's Office lists the hazardous materials that meet or exceed the thresholds for storage of hazardous materials that the state and the federal *Emergency Planning and Community Right-to-Know Act*, as amended (42 U.S.C. 1001 et seq.) have established.

3.1.13 ENVIRONMENTAL JUSTICE

> **ENVIRONMENTAL JUSTICE TERMS**
>
> **Minority:** Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other nonwhite person.
> **Low income:** Below the poverty level as defined by the U.S. Census Bureau

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs federal agencies to "promote nondiscrimination in Federal programs substantially affecting human health and the environment, and provide *minority* and low-income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment." Executive Order 12898 also directs agencies to identify and consider disproportionately high and adverse human health or environmental impacts of their actions on minority and low-income communities and American Indian tribes, as well as provide opportunities for community input to the *National Environmental Policy Act*, as amended (NEPA) (42 U.S.C. 4321 et seq.) process, which includes input on potential effects and mitigation measures. Executive Order 12898, and its associated implementing guidance, establish the framework for characterization of the affected environment for environmental justice.

Section 3.1.6.2 of this Repository SEIS discusses ties American Indians have to cultural characteristics or historic resources in the area.

This section summarizes and incorporates by reference Section 3.1.13 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-112 to 3-118) and describes the minority and low-income populations in the region of influence for the Yucca Mountain Repository that could experience disproportionately high and adverse human health or environmental effects from the Proposed Action. The analysis considered minority and poverty data in relation to the smallest census areas for which information was available. The analysis used block data for identification of minority areas and block group data for low-income areas.

The regions of influence for environmental justice in this Repository SEIS vary with resource area and correspond to the region of influence for each resource area. DOE analyzed U.S. Census Bureau block data for minority populations and block group data for low-income populations partly or completely within the regions of influence where the percentages of minority or low-income residents were meaningfully greater than average.

On August 24, 2004, the NRC issued the *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040). The policy statement recommended that an 80-kilometer (50-mile) radius be examined for licensing and regulatory actions involving power *reactors.* This policy defined the identification of low-income and minority communities as the affected area's percentage of minority or low-income population that significantly exceeds that of the state or county. NRC staff guidance defines "significantly" as 20 percentage points. Further, if either the minority or low-income population percentage in the affected area exceeds 50 percent, environmental justice analysis should provide and consider more detail. For this Repository SEIS, DOE employed the NRC policy.

3.1.13.1 State of Nevada

This Repository SEIS uses the minority and poverty data from the 2000 Census, which indicates that minority persons comprised 35 percent of the population in Nevada. Figure 3-19 shows the 2000 Census blocks in which the minority population equaled or exceeded 50 percent within the 80-kilometer (50-mile)-radius circle around Yucca Mountain. About 11 percent of the people of Nevada were living in poverty. The poverty threshold in the 2000 Census for a family of four was a 1999 income of $17,603.

3.1.13.2 Clark County

In 2000, the minority population of Clark County was approximately 40 percent of the total population. Several census blocks within the region of influence had minority populations equal to or greater than 50 percent. In Clark County, 11 percent of the population was living in poverty. There were four block groups in Clark County within or intersected by the 80-kilometer (50-mile)-radius circle around Yucca

Mountain. Block group poverty levels ranged from 0 to approximately 11 percent. No block group exceeded 31 percent.

3.1.13.3 Nye County

Based on the 2000 Census, the minority population of Nye County was approximately 15 percent. Several census blocks within the region of influence had a minority population of 50 percent or more. Approximately 11 percent of the Nye County population was living in poverty. Fifteen block groups in Nye County were within or intersected the 80- kilometer (50-mile)-radius circle around Yucca Mountain. Block-group poverty levels ranged from approximately 1 to 20 percent. No block group exceeded 31 percent.

3.1.13.4 Inyo County, California

In 2000, the minority population of California was approximately 40 percent. The minority population of Inyo County was approximately 20 percent. Several census blocks within the 80-kilometer (50-mile) radius have a minority population of 50 percent or more. About 14 percent of the people of California were living in poverty. One block group near Stewart Valley lies partly within the affected area. Approximately 13 percent of the Inyo County block groups were low-income. The percentage of low-income residents would have to be 34 percent in the Inyo County block group to be meaningfully greater than average.

3.2 Affected Environment Related to Transportation

To assess the potential impacts of its transportation-related activities, DOE must first characterize baseline environmental conditions. Section 3.2.1 provides baseline information about national transportation, and it summarizes, incorporates by reference, and updates Section 3.2.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-119 to 3-121). Section 3.2.2 refers to Chapter 3 of the Rail Alignment EIS for information about baseline conditions for transportation in Nevada of spent nuclear fuel and high-level radioactive waste and of repository supplies and commuting workers. Section 3.2.3 reports recent data on traffic conditions in the Yucca Mountain region.

3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 4 DOE sites in 34 states. DOE would transport most of these materials to the Yucca Mountain site by rail and the remainder by *overweight trucks*. Trains would travel on existing rail lines to a point in Nevada from which DOE would construct a new rail line to Yucca Mountain, as the Rail Alignment EIS explains. Trucks would travel on existing highways. DOE would use *heavy-haul trucks* for short-distance transport of spent nuclear fuel from some generator sites to nearby railheads.

The national transportation of spent nuclear fuel and high-level radioactive waste (which would include transportation in Nevada to a point of departure for the Caliente or Mina rail corridor) would use existing highways and railroads and would represent a small fraction of the existing national highway (0.0002 percent of truck miles per year) and railroad traffic (0.006 percent of railcar miles per year) (DIRS 181280-DOT 2006, all; DIRS 181282-AAR 2006, all). Because there would be no new land acquisition or construction to accommodate national transportation, this Repository SEIS focuses on potential

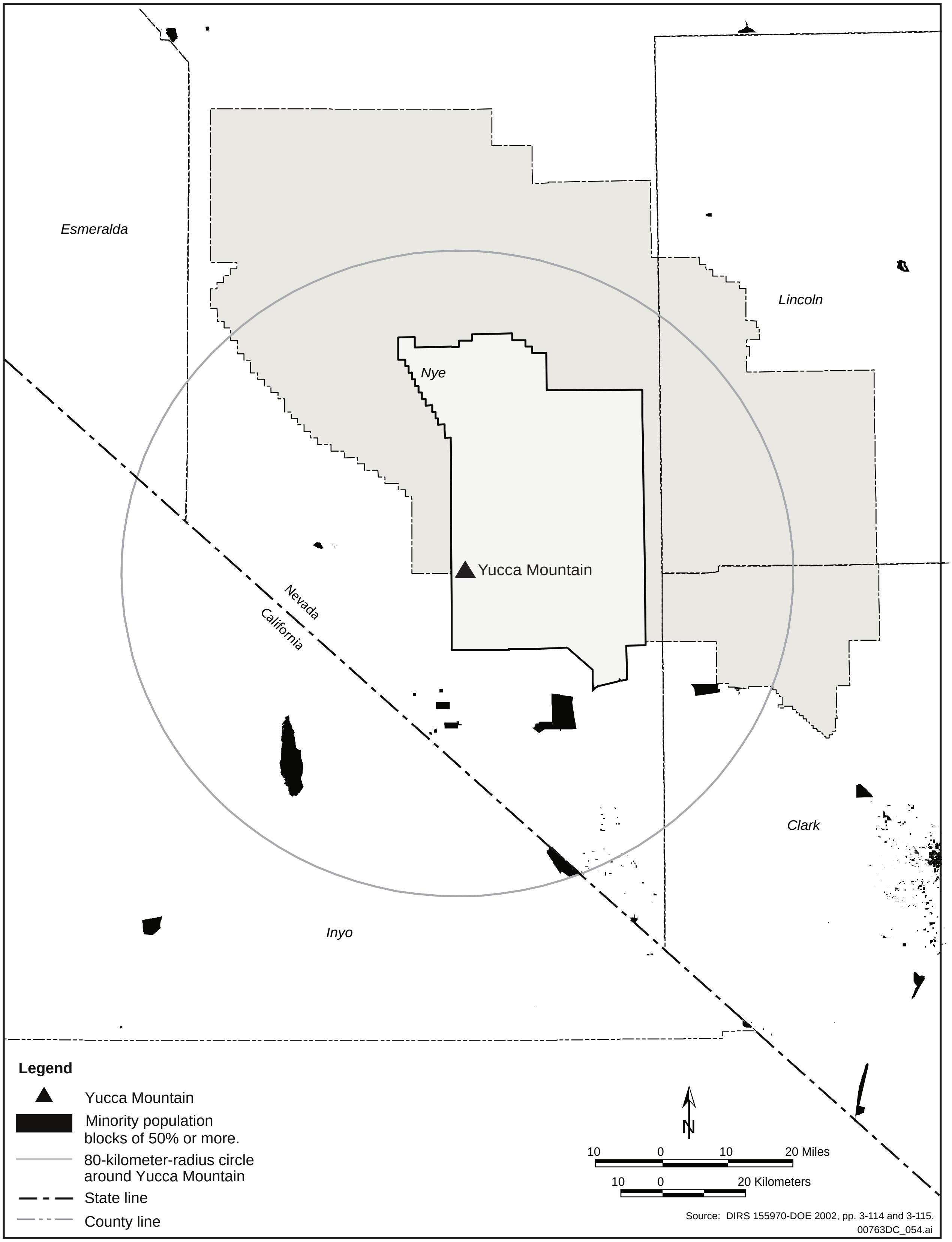

Figure 3-19. 2000 Census blocks with minority populations of 50 percent or more within the 80-kilometer (50-mile)-radius circle.

impacts to human health and safety and the potential for *accidents* along the national transportation routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

For this Repository SEIS, DOE used the TRAGIS computer program (DIRS 181276-Johnson and Michelhaugh 2003, all) to derive representative highway and rail routes for transportation of spent nuclear fuel and high-level radioactive waste for use in the analysis of health and safety impacts. TRAGIS based the estimated population densities along routes on the 2000 Census. TRAGIS identified highway routes from commercial and DOE generator sites to the proposed repository that would meet U.S. Department of Transportation regulations; no corresponding federal regulations constrain the routing of rail shipments. The analysis used population densities along the highway and rail routes to estimate human health impacts and consequences of transportation. Except in Nevada, the analysis based projected growth in populations along routes on Bureau of the Census forecasts of state populations to 2067. For routes in Nevada, DOE used 2000 Census data to develop an initial estimate of the populations within 800 meters (0.5 mile) along highways, commercial rail lines, and the potential rail *alignments* in the Caliente and Mina rail corridors. The analysis accounted for growth in populations along Nevada routes by using forecasts of population growth in Nevada counties from the REMI computer program. The analysis used population growth forecasts from Clark County, Nye County, and the Nevada State Demographer and data for each county from the 2000 Census to estimate populations in Nevada in 2067.

Appendix G describes the representative routes that DOE used for analysis in this Repository SEIS. The Department would make actual transportation mode and routing decisions on a route-specific basis during the transportation planning process, if a decision to build a repository at Yucca Mountain were made. The following sections discuss transportation routes for rail, legal-weight highway, and heavy-haul highway shipments from generator sites.

USE OF REPRESENTATIVE ROUTES IN IMPACT ANALYSIS

At this time, before receipt of a construction authorization for the repository and years before a possible first shipment, DOE has not identified the actual routes it would use to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain. However, the highway and rail routes that DOE used for analysis in this Repository SEIS are representative of routes that it could use. The highway routes conform to U.S. Department of Transportation regulations (49 CFR 397.101). These regulations, which the Department of Transportation developed for Highway Route Controlled Quantities of Radioactive Materials, require such shipments to use preferred routes that would reduce the time in transit. A preferred route is an Interstate System highway, bypass, beltway, or an alternative route designated by a state routing agency. Alternative routes can be designated by states and tribes under U.S. Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with local jurisdictions and other states. Federal regulations do not restrict the routing of rail shipments. However, for the analysis DOE assumed routes for rail shipments that would provide expeditious travel, use of high-quality track, and the minimum number of interchanges between railroads.

3.2.1.1 Rail Transportation Routes

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate with shortline rail carriers that provide service to the commercial and DOE sites. At rail yards near the sites, dedicated rail shipments would switch from shortline carriers to national mainline railroads. Figure 2-11 in Chapter 2 shows the representative rail routes that DOE analyzed and could use for shipments to Nevada. This network has about 230,000 kilometers (140,000 miles) of track that link the nation's major population centers and industrial, agricultural, energy, and mineral resources (DIRS 181282-AAR 2006, p. 3). With the exception of shortline regional railroads that serve the commercial and DOE sites, cross-country shipments would move on mainline railroads. Appendix G describes the representative rail routes.

3.2.1.2 Highway Transportation Routes

Highway transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. Figure 2-12 in Chapter 2 shows the representative truck routes that DOE analyzed and could use for shipments to Nevada. DOE calculated population density distributions along the routes to support calculations of risk to human health.

3.2.1.3 Heavy-Haul Truck Routes

For generator sites that do not have direct rail service, DOE would transport spent nuclear fuel on heavy-haul trucks to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada.

3.2.2 TRANSPORTATION IN NEVADA

Chapter 3, Sections 3.2 and 3.3, of the Rail Alignment EIS present information about baseline conditions related to the construction and operation of a rail line in Nevada. These Rail Alignment EIS sections present information drawn from the analysis of the Proposed Action and Shared-Use Alternative.

3.2.3 TRAFFIC IN THE YUCCA MOUNTAIN REGION

Main roads near Yucca Mountain are generally two-lane highways with very little daily traffic. Table 3-19 lists average daily traffic volumes along primary roads in the region of influence in 2005 (DIRS 178749-NDOT 2005, all). These traffic volumes indicate that roadways near the Yucca Mountain site rarely experience congestion. The *Highway Capacity Manual 2000* defines the levels of service, which is an industry standard for traffic engineering (DIRS 176524-Transportation Research Board 2001, all). The manual defines six levels of service that reflect the level of traffic congestion and qualify the operating conditions of a roadway. The six levels range from A to F, as best (free flow, little delay) to worst (congestion, long delays). Factors that influence the operation of a roadway or intersection include speed, delay, travel time, freedom to maneuver, traffic interruptions, comfort, convenience, and safety.

Table 3-19. Average daily traffic counts in southern Nevada, 2005.

Roadway and location of traffic count station	Vehicles per day	Level of service
U.S. 95, 0.3 kilometer north of State Route 373 (Nye County)	2,600	B
U.S. 95, 2.4 kilometers (1.5 miles) south of State Route 373 (Nye County)	2,900	B
State Route 373, 0.8 kilometer (0.5 miles) south of U.S. 95 (Nye County)	560	A
U.S. 95, 6.4 kilometers (4.0 miles) north of the Mercury Interchange (Nye County)	3,200	B
State Route 160, 0.2 kilometer (0.1 miles) south of U.S. 95 (Nye County)	990	A

Source: DIRS 178749-NDOT 2005, all.
Note: Conversion factors are on the inside back cover of this Repository SEIS.

The Highway Capacity Manual describes the levels of service as follows:

- Level of service A describes completely free-flow conditions. Individual drivers are virtually unaffected by the presence of other vehicles in the traffic stream.
- Level of service B also indicates free flow, but the presence of other vehicles becomes more noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from level of service A.
- Level of service C is in the range of stable flow, but marks the beginning of the range of flow in which operation of individual drivers becomes significantly affected by interactions with others in the traffic stream. The selection of speed is now affected by others and maneuvering requires substantial vigilance on the part of the driver.
- Level of service D represents high density but stable flow. Speed and freedom to maneuver are severely restricted, and the driver experiences a generally poor level of comfort and convenience.
- Level of service E represents operating conditions at or near capacity. All speeds are reduced to a low but relatively uniform value.
- Level of service F indicates a breakdown of traffic flow or stop-and-go traffic. This condition exists wherever the amount of traffic approaching a point exceeds the amount that can cross the point. Backups form behind such locations. Operations within the backups are characterized by stop-and-go waves, and they are extremely unstable.

The Manual generally considers levels of service A, B, and C good operating conditions in which motorists experience minor or tolerable delays of service. As Table 3-19 shows, the roads in the vicinity of Yucca Mountain are level of service A or B.

Most roads in metropolitan Clark County have levels of service that reflect congestion. The most congested area is the U.S. 93, U.S. 95, I-515, and I-15 interchanges, which are known locally as the "Spaghetti Bowl." The Spaghetti Bowl area is at level of service F during peak hours (DIRS 155779-DOE 1999, p. 3-1).

3.3 Affected Environment at Commercial and DOE Sites

DOE analyzed the impacts for the No-Action Alternative of not constructing and operating a geologic repository at Yucca Mountain. The Department assumed that spent nuclear fuel and high-level radioactive waste would remain at commercial and DOE sites throughout the United States. Because neither the No-Action Alternative nor the environmental baseline conditions at the generator sites have changed significantly, DOE has neither updated the affected environment nor reanalyzed the No-Action Alternative for this Repository SEIS. This section summarizes and incorporates by reference Section 3.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 3-183 to 3-194), which included baseline environmental factors at commercial and DOE sites such as land use requirements, radiological effluents, worker and offsite populations, and occupational and public radiation doses. These factors provided a basis for comparison of impacts between the Proposed Action and the No-Action Alternative in the Yucca Mountain FEIS.

3.3.1 SITE ENVIRONMENTAL FACTORS

3.3.1.1 Commercial Sites

The Yucca Mountain FEIS presented general site environmental factors for the 72 commercial nuclear power plant sites in the contiguous United States. Nuclear power plants typically are on flat to rolling countryside in wooded or agricultural areas. Site areas range from 0.34 to 120 square kilometers (0.13 to 46 square miles).

The average permanent staff at a nuclear power plant ranges from 800 to 2,400 workers. In addition, many temporary workers are necessary for tasks that occur during refueling and maintenance outages. In rural communities, this temporary employment can have a substantial effect on the local economy. Nuclear power plants represent investments of several billion dollars each, which generates tax revenue and often enables higher quality and more extensive public services.

Nuclear power plants release small amounts of radioactive materials to the environment through atmospheric and aquatic pathways. Releases to the atmosphere consist of noble gases, tritium, isotopes of iodine, and cesium. Radioactive effluents that sites release to aquatic pathways consist primarily of *fission* and activation products such as isotopes of cesium and cobalt. Sites monitor these materials carefully before and during effluent releases to comply with the licensed release limits.

Commercial sites routinely report worker occupational radiation exposures. The data indicate most of the radiation dose to workers is from external radiation rather than internal exposure to inhaled or ingested radioactive material from the operation of the *nuclear reactor*. In 1999, the total collective occupational dose for all operating commercial reactors was almost 14,000 person-rem. DOE based this collective dose on data from 114,000 monitored personnel. Of these monitored workers, about half had no measurable dose.

The Yucca Mountain FEIS listed and discussed radiation exposures to the public at commercial sites. In 1992, the estimated total population doses for populations living within 80 kilometers (50 miles) of operating nuclear power reactors were 32 person-rem by waterborne pathways and 15 person-rem by airborne pathways. Estimated population dose commitments from both pathways varied widely among the sites.

3.3.1.2 DOE Sites

The Yucca Mountain FEIS presented general site environmental factors for five DOE sites at which spent nuclear fuel and high-level radioactive waste exist. The environmental factors were land use, socioeconomics, and occupational radiation exposure. Large expanses of federally owned land surround and buffer the public from potential effects at three of the DOE sites—the Hanford Site, Idaho National Laboratory, and Savannah River Site. The Fort St. Vrain Independent Spent Nuclear Fuel Installation in Colorado and the West Valley Demonstration Project in New York are on much smaller tracts with nearby lands having low density and mostly agricultural and residential land uses.

Based on their large employment bases, the Hanford Site, Idaho National Laboratory, and Savannah River Site represent a substantial portion of local workforces. In addition to base employment, DOE sites contribute to the local economy through the creation of indirect employment and through the local purchase of goods and services.

The Yucca Mountain FEIS discussed occupational radiation exposures for workers at the DOE sites. For the five DOE sites, the 1999 total collective dose for workers was about 380 person-rem. There were almost 6,000 individuals with measurable doses, and the average annual dose was about 60 millirem per person. The Fort St. Vrain site reported no measurable doses for 1999. In the Yucca Mountain FEIS, DOE estimated the collective doses for populations who lived within 80 kilometers (50 miles) of the five DOE sites. In 1999, the total estimated offsite population dose was about 7.1 person-rem. About 2.5 million people received this dose; the average was about 0.003 millirem per person, which is a very small fraction of the annual dose from natural background radiation of about 300 millirem in the United States.

3.3.2 REGIONAL ENVIRONMENTAL FACTORS

DOE used a regional approach that divided the continental United States into five regions (Figure 3-20) to analyze the No-Action Alternative in the Yucca Mountain FEIS. The affected environment for each region includes the inventory of spent nuclear fuel and high-level radioactive waste in the region, climatic parameters, groundwater flow times, affected waterways (rivers), river flow, and the identification of populations that depend on drinking water from those waterways. The use of these regional environmental factors resulted in representative values that are not susceptible to short-term or frequent fluctuations but instead evolve over long periods (decades). As a consequence, the regional factors would not be different from those in the Yucca Mountain FEIS. Tables 3-20 through 3-23 provide the regional environmental factors from the FEIS that were used in the No-Action Alternative analyses.

Precipitation, rain days, wet days, and temperature are important climatic parameters to material degradation times and rates of release. Table 3-21 lists the regional values for each parameter along with precipitation chemistry (pH, chloride anions, and sulfate anions). Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops, rivers, or streams. Table 3-22 lists the ranges of groundwater flow times in each region. The analysis calculated these ranges as the estimated times in years that it takes for groundwater, and separately for contaminants in the groundwater, to reach the surface-water resource nearest to each site at which people could obtain drinking water. The range is the shortest and longest flow time depending on the site. Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated

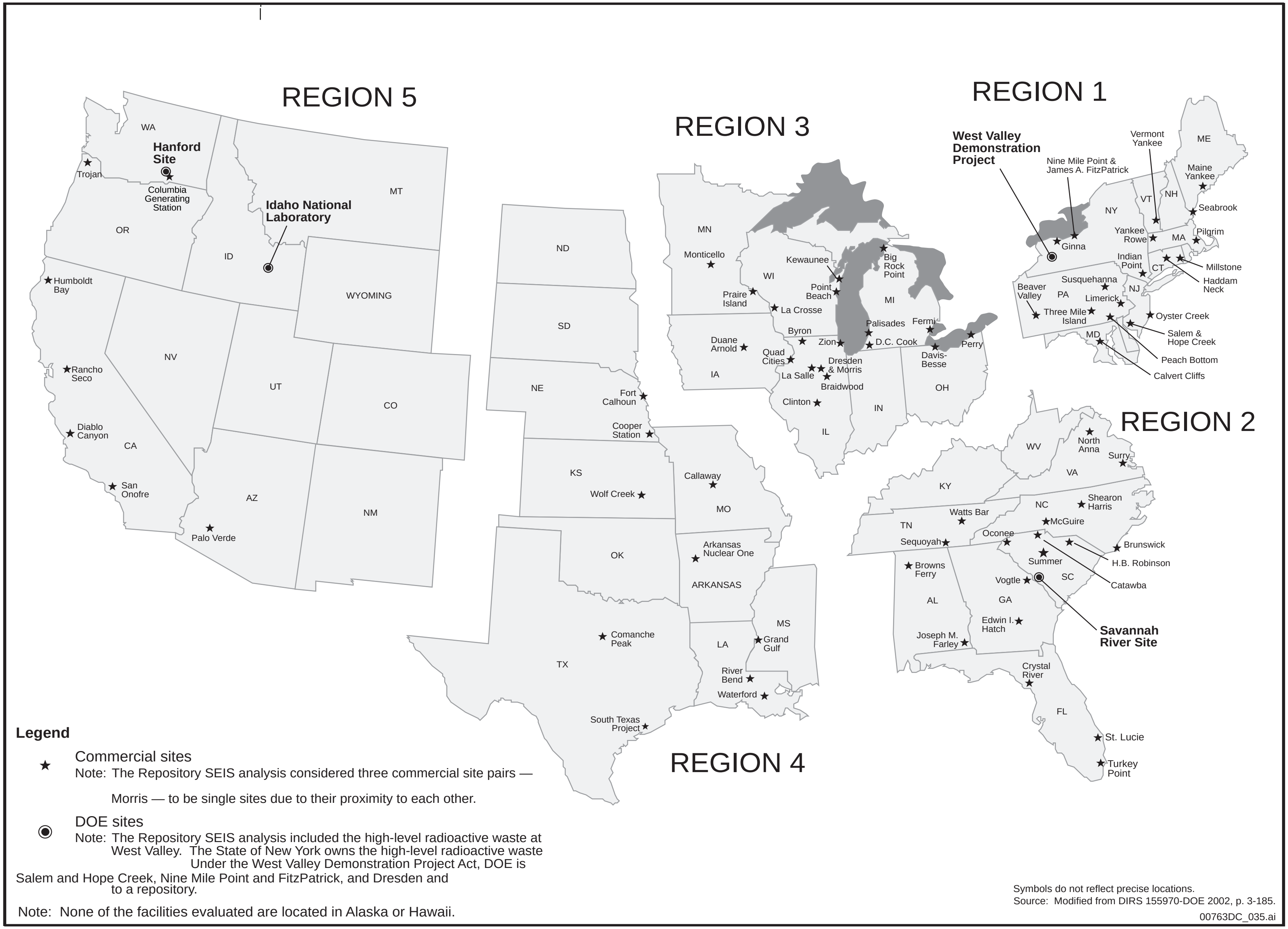

Figure 3-20. Commercial and DOE sites in each No-Action Alternative analysis region.

surface water. Table 3-23 lists the number of people who would use the public drinking water systems that degradation of radioactive materials could affect.

Table 3-20. Proposed Action quantities of spent nuclear fuel (metric tons of heavy metal) and canisters of high-level radioactive waste in each geographic region.[a]

Region	Commercial spent nuclear fuel	DOE spent nuclear fuel	High-level radioactive waste
1	16,800	0	300
2	18,900	30	6,000
3	14,700	0	0
4	7,200	0	0
5	5,400	2,300	2,000
Totals	63,000	2,300	8,300

Source: DIRS 155970-DOE 2002, p. 3-191.
a. Totals might differ from sums due to rounding.

Table 3-21. Regional environmental parameters.

Region	Precipitation rate (centimeters per year)	Percent rain days (per year)	Percent wet days (per year)	pH	Precipitation chemistry: Chloride anions (weight percent)	Precipitation chemistry: Sulfate anions (weigh percent)	Average temperature (°C)[a]
1	110	30	31	4.4	6.9×10^{-5}	1.5×10^{-4}	11
2	130	29	54	4.7	3.9×10^{-5}	9.0×10^{-5}	17
3	80	33	42	4.7	1.6×10^{-5}	2.4×10^{-4}	10
4	110	31	49	4.6	3.5×10^{-5}	1.1×10^{-4}	17
5	30	24	24	5.3	2.1×10^{-5}	2.5×10^{-5}	13

Source: DIRS 155970-DOE 2002, p. 3-192.
Note: Conversion factors are on the inside back cover of the Repository SEIS.

Table 3-22. Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

Region	Contaminant K_d[a,b] (milliliters per gram)	Unsaturated zone: Water flow time	Unsaturated zone: Contaminant flow time	Saturated zone: Groundwater flow time	Saturated zone: Contaminant flow time	Total contaminant flow time
1	0–100	0.7–4.4	0.4–2,100	0.3–56	10–5,000	10–6,000
2	10–250	0.6–10	35–5,000	3.3–250	11–310,000	460–310,000
3	10–250	0.5–14	32–1,500	1.3–410	9–44,000	65–45,000
4	10–100	0.2–7.1	110–2,300	3.9–960	300–520,000	460–520,000
5	0–10	0.9–73	14–4,700	1.7–170	0–25,000	200–26,000

Source: DIRS 155970-DOE 2002, p. 3-192.
a. K_d = equilibrium adsorption coefficient.
b. The K_d would be 0 if there were no soil at the site.

Table 3-23. Public drinking water systems and the populations that use them in the five regions.

Region	Drinking water systems	Population
1	85	10,000,000
2	150	5,600,000
3	150	12,000,000
4	95	600,000
5	6	2,800,000
Totals	486	31,000,000

Source: DIRS 155970-DOE 2002, p. 3-194.

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4

Environmental Impacts of Repository Construction, Operation and Monitoring, and Closure

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4. ENVIRONMENTAL IMPACTS OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes preclosure environmental impacts that could result from the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

Preclosure refers to the period from the beginning of construction through final repository closure and includes the periods of construction, operations, monitoring, and closure that the U.S. Department of Energy (DOE or the Department) analyzed. Chapter 5 of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) discusses the environmental consequences of postclosure repository performance—that period out to 10,000 years and beyond after repository closure. Chapter 6 discusses the environmental consequences of transportation, and Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from activities at the repository site and from offsite manufacturing of repository components [for example, transportation, aging, and disposal (TAD) canisters, waste packages, and drip shields]. It also describes the impacts from proposed special-use airspace above the repository. The methods DOE used in the analyses to predict the potential impacts in this section are conservative. This means that the predicted results are likely higher than the actual values that would be measured or observed. Examples of conservative methods include not considering best management practices for dust suppression in the predictive release and concentration analyses for particulate matter, not taking credit for demonstrated successful remediation and reclamation efforts in the disturbed land analyses, and not applying DOE radiation protection program objectives such as As Low As Reasonably Achievable into worker radiation exposure analyses. The occupational and human health and safety and accident analyses use multiple methods that are conservative, which increases the likelihood that the predicted results would be higher than the actual measured or observed values. Each of the resource sections in this chapter and any associated appendices provide the specifics of the analyses.

Since DOE completed the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS), the Department has modified its repository design and operational plans. These modifications have resulted in changes to information for the analyses of potential environmental impacts and, therefore, resulted in new impact analyses for each of the 15 resource and subject areas evaluated in this Repository SEIS. Land disturbance, water and fuel use, number of repository workers, and credible accidents from repository-related activities are examples of information DOE used for analysis of impacts that have changed since the completion of the FEIS. This new information, in turn, resulted in changes to the impact analyses for multiple resource areas. For example, new information for land disturbance required a reevaluation of impacts to land use and ownership, air quality, hydrology, biological resources and soils, cultural resources, aesthetics, and noise.

Where noted in this chapter of the Repository SEIS, DOE summarizes, incorporates by reference, and updates Chapter 4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-1 to 4-128) and presents new information, as applicable, from studies and investigations that continued after the completion of the Yucca Mountain FEIS. If the Department did not use information from the FEIS, but rather based the impact analysis in a subsection on new information, the introduction to that subsection so states and does not reference the FEIS. To ensure that the source of the information is clear, DOE states it is summarizing, incorporating by reference, and updating the FEIS in the introduction to each applicable section or subsection of Section 4.1.

Section 4.2 describes potential environmental impacts of waste retrieval if this option became necessary. The current concept for retrieval has not changed from that which DOE analyzed in the Yucca Mountain FEIS, which is summarized and incorporated by reference.

Section 4.3 presents a new section that evaluates actions that include repair, replacement, or improvement of existing Yucca Mountain Project facilities that would enable DOE to continue ongoing operations, scientific testing, and routine maintenance until the U.S. Nuclear Regulatory Commission (NRC) decides whether to authorize construction of a repository. DOE needs to improve the Yucca Mountain site infrastructure not only to ensure safety for workers, regulators, and visitors, but also to comply with applicable environmental, health, and safety standards and DOE Directives. The Department could implement these specific elements before it received construction authorization from NRC. Before implementation, a Record of Decision on this Repository SEIS will present any decisions DOE might make in relation to the improvements. These actions would be independent of repository construction.

4.1 Preclosure Environmental Impacts of Construction, Operation and Monitoring, and Closure of a Repository

This section describes the preclosure environmental impacts from the Proposed Action. DOE has described these impacts by the analytical periods of the Proposed Action—construction, operations, monitoring, and closure—and the activities (some of which overlap) associated with them.

The following paragraphs summarize the periods and associated activities DOE has evaluated in this Repository SEIS. Chapter 2 (Table 2-1) of this Repository SEIS describes these periods and activities in detail.

Construction Analytical Period (5 Years)

The construction analytical period would begin when NRC authorized DOE to build the repository. For analysis purposes, this Repository SEIS assumed construction would begin in about 2012 and would be complete on receipt of the NRC license to receive and possess radiological materials. Site preparation would include such activities as the demolition or relocation of existing facilities, excavation of fill material down to the original ground contours, and placement and compaction of engineered backfill in the areas of facility construction. The Department would construct new surface facilities and balance of plant facilities (which would include infrastructure) necessary for initial receipt and emplacement of spent nuclear fuel and high-level radioactive waste. In addition, DOE would begin development (excavation and preparation for use) of the subsurface facility.

Operations Analytical Period (up to 50 Years)

For this analysis, DOE assumed that repository operations would begin in 2017, after it received a license from NRC to receive and possess spent nuclear fuel and high-level radioactive waste. The operations period would include continued construction of surface facilities and development (excavation and preparation for use) of the subsurface repository, receipt and handling of spent nuclear fuel and high-level radioactive waste in surface facilities, and emplacement of these materials in the completed portions of the repository. Surface facility construction activities would continue for approximately 5 years into the operations period. Development activities would last 22 years and would be concurrent with handling and emplacement. Handling and emplacement activities would last up to 50 years.

Monitoring Analytical Period (50 Years)

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of a waste package and would continue through the closure period. After the completion of the operations analytical period (emplacement), the monitoring analytical period that DOE used for analysis in this SEIS would begin. Monitoring would be the primary activity. DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary. This period would last 50 years. DOE has also analyzed the potential for a monitoring period of up to 250 years. This analysis is included in Appendix A, Section A.6

Closure Analytical Period (10 Years)

Repository closure would occur after DOE applied for and received a license amendment from NRC. Closure would take 10 years, and would occur during the last 10 years of the monitoring period. The closure of the repository facilities would include the following activities:

- Emplacing the drip shields
- Removing and salvaging reusable equipment and materials;
- Backfilling and sealing subsurface-to-surface openings;
- Constructing monuments to mark the area;
- Decommissioning and demolishing surface facilities; and
- Restoring the surface to its approximate condition before repository construction.

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land use and ownership impacts from activities under the Proposed Action. The region of influence for land use and ownership impacts is the analyzed land withdrawal area and an area to the south that DOE proposes to use for offsite facilities and an access road from U.S. Highway 95. Congress would define the actual land withdrawal area. The analysis considered impacts from direct disturbances in relation to proposed repository construction, operation and monitoring, and closure as well as construction and operation of the access road and offsite facilities. It also considered impacts from the transfer of lands to DOE control. Section 4.1.1.1 summarizes, incorporates by reference, and updates Section 4.1.1.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-5 to 4-6). Section 4.1.1.2 provides a new analysis based on the current design and operational plan. Section 4.1.15 of this Repository SEIS describes the requirement for airspace restrictions and the impacts to airspace use from these restrictions.

4.1.1.1 Impacts to Land Use and Ownership from Land Withdrawal

To develop a Yucca Mountain repository, DOE would obtain permanent control of an area of approximately 600 square kilometers (150,000 acres) in southern Nevada on lands that are currently managed by the Bureau of Land Management, U.S. Air Force (Nevada Test and Training Range), and DOE (Nevada Test Site) (Chapter 3, Section 3.1.1). Land withdrawal is the method by which the Federal Government gives exclusive control of land it owns to a particular agency for a particular purpose. NRC regulations require that repository operations areas and postclosure controlled areas be held free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements for rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

NRC licensing conditions for a repository (10 CFR 63.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. Only Congress has the power to withdraw federal lands permanently for the exclusive purposes of specific agencies. If Congress authorized and directed the withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal. In the absence of specific direction to another federal agency, the Bureau of Land Management would ordinarily administer details of a Congressional withdrawal in accordance with the provisions of 43 CFR Part 2300.

At present, the Bureau of Land Management administers approximately 180 square kilometers (44,000 acres) of the analyzed land withdrawal area. Most of this area is associated with the current right-of-way (N-47748) for previous site characterization activities. As such, with the exception of about 17.4 square kilometers (4,300 acres) near the site of the proposed repository and an existing patented mining claim, these lands are available for public uses such as mineral exploration, recreation, and grazing. Congress granted these rights under various federal laws, such as the *Federal Land Policy and Management Act of 1976*, as amended (43 U.S.C. 1701 et seq.), and future legislation for a permanent withdrawal would likely be consistent with these laws and implementing regulations.

The Bureau of Land Management would evaluate and adjudicate the validity of all mining claims on the portion of the land withdrawal area that was under its control before the permanent legislative withdrawal. DOE would provide just compensation for the acquisition of valid property rights. The proposed withdrawal would not affect the 0.81 square kilometer (200 acres) of private land (Patented Mining Claim No. 27-83-0002) in the Cind-R-Lite patented claim for mining of cinder block material (Section 3.1.1.2). That area would remain in private ownership.

DOE, in consultation with the U.S. Air Force and the Bureau of Land Management as appropriate, would manage the withdrawn land in accordance with the *Federal Land Policy and Management Act of 1976*, the conditions of the permanent legislative withdrawal set forth by Congress, and other applicable laws. Certain public uses considered consistent with the purposes of the withdrawal would likely continue, such as the Nye County Early Warning Drilling Program to monitor for potential repository releases.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring periods, DOE would disturb or clear land for subsurface and surface facility construction. The total land disturbance for the proposed repository, access road, and offsite facilities would be approximately 9 square kilometers (2,200 acres).

Land disturbances would include approximately 8.5 square kilometers (2,100 acres) of small noncontiguous areas inside the analyzed land withdrawal area. Most of the surface facilities and disturbed land would be in the geologic repository operations area (Chapter 2, Section 2.1.2). Repository activities would not conflict with current land uses on adjacent lands under control of the Bureau of Land Management, U.S. Air Force, and DOE.

The Proposed Action would disturb approximately 0.57 square kilometer (140 acres) of Bureau of Land Management land outside the analyzed land withdrawal area for construction of offsite facilities and an access road from U.S. Highway 95. DOE would relocate the current access road intersection with U.S. Highway 95 approximately 0.39 kilometer (0.24 mile) to the southeast to line up with the intersection of Nevada State Route 373 and U.S. Highway 95. The projected volume of traffic could be handled by acceleration and deceleration lanes and a controlled access at the Gate 510/State Route 373/U.S. Highway 95 intersection. The estimated area for such an intersection would be approximately 0.11 square kilometer (28 acres). Because the existing highway through this area uses approximately 0.065 square kilometer (16 acres), only about 0.049 square kilometer (12 acres) of new land would be necessary. Approximately 0.097 square kilometer (24 acres) would be necessary for 1.6 kilometers (1 mile) of new road about 61 meters (200 feet) wide. Relocation of the road would require cooperation with Nye County plans for the Amargosa Valley area, a right-of-way from the Bureau of Land Management, and coordination with the Nevada Department of Transportation.

The analysis assumed the training facility, the Sample Management Facility, a marshalling yard and warehouse, and temporary housing for construction workers would be near Gate 510 on Bureau of Land Management land outside the analyzed land withdrawal area. As noted in Section 3.1.1.1 of this Repository SEIS, the Bureau of Land Management has designated for disposal a portion of the land south of the analyzed land withdrawal area and Nye County has formally notified the Bureau of its intent to purchase up to 1.2 square kilometers (296 acres) for development that could potentially host these facilities (DIRS 182804-Maher 2006). The training facility would require a 0.02-square-kilometer (5-acre) parcel for the facility, associated parking, landscaping, and access. The Sample Management Facility would require 0.012 square kilometer (3 acres). DOE could build the Sample Management Facility inside the analyzed land withdrawal area; however, to be conservative, the analysis assumed it would be outside the land withdrawal area. The marshalling yard and warehouse would require fencing, offices, warehousing, open laydown, and shops on 0.2 square kilometer (50 acres). Temporary housing accommodations for construction workers would require approximately 0.1 square kilometer (25 acres), but DOE would reclaim the lands when it no longer needed to use them. DOE could use the temporary accommodations for railroad construction workers in the Crater Flat area, which is part of the proposal in the Rail Alignment EIS. Depending on the need for housing, the Department could use the rail construction camp either in lieu of temporary accommodations at the southern boundary or in addition to those accommodations.

The Bureau of Land Management controls lands to the south of the analyzed land withdrawal area and manages them in accordance to the *Record of Decision for the Approved Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 176043-BLM 1998, all). This plan designates corridors in its planning area to avoid Areas of Critical Environmental Concern. The proposed activities outside the analyzed land withdrawal area would not overlap such areas (DIRS 103079-BLM 1998, Map 2-7), and therefore they do not conflict with the Bureau's management plan.

Chapter 6 discusses land use and impacts from construction and operation of a rail line in Nevada and associated rail facilities.

During closure, DOE would restore disturbed areas that were no longer needed to their approximate condition before repository construction.

Surface disturbance inside the analyzed land withdrawal area of approximately 8.5 square kilometers (2,100 acres) would represent a small amount of the 600 square kilometers (150,000 acres) of the withdrawal. Further, 2.43 square kilometers (600 acres) are considered previously disturbed (Chapter 3, Section 3.1.1.2). DOE also would disturb approximately 0.48 square kilometer (120 acres) of previously undisturbed land outside the analyzed land withdrawal area but would avoid conflicts with surrounding land uses to the extent possible. Therefore, land use impacts from activities under the Proposed Action would be small.

4.1.2 IMPACTS TO AIR QUALITY

This section updates potential impacts to air quality in the Yucca Mountain region from release of nonradiological air pollutants during construction, operation and monitoring, and closure of the proposed repository since the Yucca Mountain FEIS. The Department has reanalyzed impacts to air quality for this Repository SEIS based on the modified design that Chapter 2 describes. The region of influence is an area with a radius of approximately 80 kilometers (50 miles) around the Yucca Mountain site. Appendix B discusses the methods DOE used for air quality analysis for this Repository SEIS, including the new model for estimation of the annual and short-term (24-hour or less) air quality impacts at the proposed repository, and provides additional data and intermediate results the Department used to estimate air quality impacts. Section 4.1.7.2 discusses health impacts associated with radiological air quality.

> **PARTICULATE MATTER**
>
> **$PM_{2.5}$**
> Particulate matter with an aerodynamic diameter of 2.5 micrometers or less (about 0.0001 inch).
>
> **PM_{10}**
> Particulate matter with an aerodynamic diameter of 10 micrometers or less (about 0.0004 inch).
>
> As a frame of reference, the diameter of the average human hair is approximately 70 micrometers.

Sources of nonradiological air pollutants at the repository site would include fugitive dust emissions from land disturbances and excavated rock handling; fugitive dust emissions from concrete batch plant operations; and nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter emissions from fossil fuel use. DOE used the American Meteorological Society/Environmental Protection Agency Regulatory Model computer program (AERMOD) to estimate the annual and short-term (24-hour or less) air quality impacts. The Department evaluated impacts for five criteria pollutants: carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter. The analysis did not quantitatively address the criteria pollutant lead because there would be no sources of airborne lead at the repository. DOE used the National Ambient Air Quality Standards, described in Chapter 3, Section 3.1.2.1, to analyze air quality impacts. The National Ambient Air Quality Standards set limits to protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly. In addition to the criteria pollutants, DOE evaluated potential impacts from cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. Erionite is an uncommon zeolite mineral that underground construction could encounter, but the mineral appears to be absent or rare at the proposed repository depth and location. Erionite would not affect air quality in the area around the repository, and DOE did not consider it in the analysis. Ozone is not emitted directly into the atmosphere, but is created by complex chemical reactions of precursor pollutants in the presence of sunlight. The precursor pollutants are nitrogen oxides (including nitrogen dioxide) and *volatile organic compounds*. The major source for volatile organic compounds and nitrogen dioxide is the burning of fossil fuels. DOE's analysis of ozone evaluated the emissions of these precursors.

CONFORMITY

Section 176(c)(1) of the *Clean Air Act* requires federal agencies to ensure that their actions conform to applicable implementation plans for the achievement and maintenance of National Ambient Air Quality Standards for criteria pollutants. To achieve conformity, a federal action must not contribute to new violations of standards for ambient air quality, increase the frequency or severity of existing violations, or delay timely attainment of standards in the area of concern (for example, a state or smaller air quality region). The EPA general conformity regulations (40 CFR Part 93, Subpart B) contain guidance for determination of whether a proposed federal action would cause emissions to be above certain levels in locations that EPA designated as nonattainment or maintenance areas. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as unclassifiable. The quality of the air in the region of influence is unclassifiable because of limited air quality data (40 CFR 81.329). For regulatory purposes, EPA considers unclassifiable areas to be in attainment.

A portion of Clark County is in nonattainment for carbon monoxide, PM_{10}, and the 8-hour ozone standard (40 CFR Part 81). These nonattainment areas are outside the 80-kilometer (50-mile) region of influence for air quality. A portion of Inyo County, California, is in nonattainment for the PM_{10} standard (40 CFR Part 81). This nonattainment area is also outside the 80-kilometer region of influence for air quality. A portion of Nye County near the town of Pahrump has a maintenance status for PM_{10}. This maintenance area is at the edge of the 80-kilometer region of influence for air quality.

The provisions of the conformity rule apply only where the action is in a federally classified nonattainment or maintenance area. As already specified, there are no nonattainment areas in the region of influence for air quality. The repository would be less than 80 kilometers from a PM_{10} maintenance area, and PM_{10} impacts from repository activities would be very small. Although the conformity regulations would not apply to the Proposed Action, DOE would work with Nye County to ensure that the Proposed Action would not contribute to additional violations of PM_{10} air quality standards in the maintenance area.

This conformity review applies only to those portions of the Proposed Action that are in the 80-kilometer (50-mile) region of influence for air quality. The conformity review for the balance of the rail alignment is in the Rail Alignment EIS.

The air quality analysis evaluated impacts at the potential locations of maximally exposed individual members of the public. (Section 4.1.7.1 presents impacts to workers.) The analysis defined the locations as the nearest points of unrestricted public access outside the analyzed land withdrawal area. For periods of 1 year or longer, the analysis assumed maximally exposed individuals were at the southern boundary of the land withdrawal area, the closest location they could be for long periods during repository activities. The maximum air quality impact (that is, air concentration) that would result from repository activities could occur at different locations along the boundary of the land withdrawal area depending on the release period and the averaging time. The maximally exposed individual would be the person at the location with the highest concentration per release period and averaging time. Appendix B, Section B.3 describes the locations of maximally exposed individuals in greater detail.

4.1.2.1 Impacts to Air Quality from Construction

This section describes nonradiological air quality impacts that could occur during the construction analytical period of the proposed repository. For analytical purposes, DOE assumed that the construction period would last 5 years and that construction activities would be evenly distributed over the period. Activities during this period would include infrastructure upgrades, excavation of fill material, subsurface excavation to prepare the repository for initial emplacement operations, construction of surface facilities in the geologic repository operations area and South Portal development area, and construction of ventilation shafts and associated access roads. Table 2-1 of this Repository SEIS lists activities during the construction period.

Construction activities would result in emissions of air pollutants from subsurface and surface activities. These emissions would include the following:

- Fugitive dust in the form of PM_{10} (particulate matter with an aerodynamic diameter of 10 micrometers or less) during site preparation from the excavation of undocumented fill in the geologic repository operations area,
- Fugitive dust (PM_{10}) from land-disturbing activities during surface construction, which would include the access road, utility corridor, surface facilities, aging pads, and Rail Equipment Maintenance Yard and other rail facilities,
- Fugitive dust (PM_{10}) from the placement and maintenance of excavated rock at a surface storage pile,
- Particulate matter (PM_{10}) from ventilation exhausts during subsurface excavation,
- Particulate matter (PM_{10}) from three concrete batch plants, and
- Gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide) and particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$) from fossil fuel consumption by construction vehicles.

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the analyzed land withdrawal area for repository activities that would occur in that area. Maximum concentrations of carbon monoxide, nitrogen dioxide, sulfur dioxide, and $PM_{2.5}$ at the analyzed land withdrawal area boundary would be small. The maximum concentration of PM_{10} would be within the regulatory limit. Although normal dust suppression measures such as watering the ground surface would reduce the PM_{10} concentration, the analysis did not consider such measures.

Table 4-1. Maximum construction analytical period concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Carbon monoxide[e]	8-hour	10,000	16	0.16
	1-hour	40,000	130	0.32
Nitrogen dioxide[e]	Annual	100	0.043	0.043
Sulfur dioxide[e]	Annual	80	0.00016	0.00020
	24-hour	365	0.023	0.0062
	3-hour	1,300	0.18	0.014
PM_{10}[e]	24-hour	150	59	40
$PM_{2.5}$[e]	Annual	15	0.0024	0.016
	24-hour	35	0.34	1.0
Cristobalite	Annual	10[f]	0.048	0.48[f]

a. Appendix B describes the analysis of maximum concentrations and percent of regulatory limits.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.22097 (Table 3-5).
d. Sum of highest estimated concentrations at the accessible land withdrawal boundary regardless of direction (Appendix B contains more information). Does not include background concentrations. Table 3-2 in Chapter 3 lists the highest measured background concentrations at Yucca Mountain. The maximum concentrations would not exceed the regulatory limits after adding the highest background concentrations.
e. DOE assumed that construction vehicles would be between model years 2006 and 2010 and would meet Tier 3 emission standards.
f. There are no regulatory limits for public exposure to cristobalite. DOE used a comparative benchmark of 10 micrograms per cubic meter (Section 4.1.2.1 and Appendix B, Section B.1).

The maximum annual concentration of the ozone precursor nitrogen dioxide would be less than 0.05 percent of the regulatory limit and the annual emissions would be less than 4 percent of the total estimated nitrogen oxide emissions of approximately 1.3 million kilograms (1,400 tons) in Nye County during 2002 (DIRS 177709-EPA 2006, all). The other ozone precursor, volatile organic compounds, would have estimated annual emissions of about 5,300 kilograms (about 12,000 pounds) from repository construction activities. Because Yucca Mountain is in an attainment area for ozone, the analysis compared the estimated annual release of volatile organic compounds to the Prevention of Significant Deterioration of Air Quality emission threshold for volatile organic compounds for stationary sources (40 CFR 52.21). The volatile organic compound emission threshold is 36,000 kilograms (80,000 pounds) per year, so the peak annual release from the repository would be well below the level. The impact of these pollutants on ozone formation should not cause violations of the ozone standard.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for workers who could inhale the particles during subsurface excavation operations (Section 4.1.7.1). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of the lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear.

Cristobalite would be emitted from the subsurface by the ventilation system during excavation operations; releases would be in the form of fugitive dust from the excavated rock pile. Fugitive dust from the rock pile would be the largest potential source of cristobalite exposure to surface workers and to the public. DOE would perform evaluations of airborne crystalline silica at Yucca Mountain during routine operations and tunneling. For this analysis, DOE assumed that 28 percent of the fugitive dust from the rock pile and subsurface excavation would be cristobalite. This reflects the maximum cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Using the parent rock percentage overestimates the airborne cristobalite concentration because studies of ambient and occupational airborne crystalline silica have shown that most of the silica is coarse (not respirable) and that larger particles do not stay airborne but rapidly deposit on the surface. Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal boundary during the construction analytical period.

There are no regulatory limits for public exposure to cristobalite, even though there are regulatory limits for worker exposure (29 CFR 1910.1000). Due to the lack of regulatory limits for public exposure to cristobalite, this analysis used a comparative benchmark of 10 micrograms per cubic meter. A U.S. Environmental Protection Agency (EPA) health assessment stated that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 micrograms per cubic meter multiplied by years (DIRS 103243-EPA 1996, p. 1-5). Over a 70-year lifetime, this benchmark would correspond to an annual average exposure concentration of approximately 14 micrograms per cubic meter. For added conservatism, the analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark. Table 4-1 compares the estimated cristobalite concentrations and this assumed benchmark. The postulated annual average exposure would be less than 0.5 percent of the benchmark. DOE would use common dust suppression techniques (such as water spraying) to reduce releases of fugitive dust, and thus cristobalite, from the excavated rock pile.

Surface construction outside the analyzed land withdrawal area (that is, off the Yucca Mountain site) would occur during the construction analytical period. Offsite construction would include an intersection at U.S. Highway 95, an offsite Sample Management Facility, and other areas such as a training facility and an offsite marshalling yard for construction materials. Because these activities would be outside the land withdrawal area, the potential location of the maximally exposed individual member of the public would not be at the boundary of that area, as with activities within the area. The maximally exposed member of the public would be adjacent to the offsite construction. Table 4-2 lists the maximum estimated impacts to air quality as a result of offsite construction. The maximum concentrations are for individuals 100 meters (330 feet) from the construction activities (Appendix B, Section B.3). Although DOE would use dust suppression measures to reduce the PM_{10} concentration, the impact analysis did not consider such measures.

The maximally exposed individual member of the public who was near offsite construction also would be exposed to concentrations of criteria pollutants from activities in the land withdrawal area. Therefore, the maximum air quality impact for a person near offsite construction must include a contribution from activities in the land withdrawal area. Because PM_{10} is the criteria pollutant that is closest to reaching its regulatory limit, DOE selected it for use in a worst-case scenario for air quality impact analysis. Individuals near offsite construction could be affected by a maximum PM_{10} concentration of 53 micrograms per cubic meter from repository construction activities that occurred in the land withdrawal area. This is less than 36 percent of the PM_{10} regulatory limit. Therefore, the total maximum PM_{10} air quality impact near the offsite construction could be about 78 percent of the regulatory limit. DOE calculated this value by adding the less than 36 percent of the regulatory limit from activities in the land withdrawal area to the 43 percent of the regulatory limit from offsite construction activities. (The scenario does not consider background concentrations of PM_{10}. Table 3-2 in Chapter 3 lists the highest

Table 4-2. Maximum construction period concentration of criteria pollutants 100 meters from offsite construction activities (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration	Percent of regulatory limit
Carbon monoxide[c]	8-hour	10,000	21	0.21
	1-hour	40,000	170	0.42
Nitrogen dioxide[c]	Annual	100	1.0	1.0
Sulfur dioxide[c]	Annual	80	0.0040	0.0051
	24-hour	365	0.032	0.0088
	3-hour	1,300	0.24	0.019
PM_{10}	24-hour	150	64	43
$PM_{2.5}$[c]	Annual	15	0.057	0.38
	24-hour	35	0.49	1.4

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.22097 (Table 3-5).
c. DOE assumed construction vehicles would be between model years 2006 and 2010 and would meet Tier 3 emission standards.

measured background concentration of PM_{10} at Yucca Mountain.) This most conservative case assumes that peak offsite construction would occur simultaneously with peak construction in the land withdrawal area. It does not consider normal dust suppression methods. The actual air quality impact for PM_{10} should be less than the most conservative case.

4.1.2.2 Impacts to Air Quality from Operations

This section describes potential nonradiological air quality impacts during the operations analytical period of the Yucca Mountain repository. For analytical purposes, this period would begin on receipt of an NRC license amendment to receive and possess spent nuclear fuel and high-level radioactive waste, and would include receipt, handling, aging, emplacement, and monitoring of these materials. DOE plans to continue surface construction during the first 5 years and to continue subsurface development during the first 25 years of this period. The maximum air quality impacts would occur during the first 5 years of the period, when surface construction and operations activities would occur at the same time. The operations period would last up to 50 years and would end on emplacement of the last waste package.

Continued subsurface development would result in the release of fugitive dust (PM_{10}) from the ventilation exhausts. Activities at the surface would result in the following air emissions during this period:

- Fugitive dust (PM_{10}) from continued land-disturbing construction activities on the surface, which would include the North Construction Portal, remaining facilities at the North Portal, and a remaining aging pad;
- Fugitive dust (PM_{10}) from the excavation, placement, and maintenance of rock at the excavated rock storage pile;
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile;
- Particulate matter (PM_{10}) from the concrete batch plants;

- Gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, and sulfur dioxide) and particulate matter ($PM_{2.5}$) from vehicles during surface construction and the emplacement of waste packages; and
- Gaseous criteria pollutants and particulate matter ($PM_{2.5}$) from diesel boilers and standby and emergency diesel generators.

Table 4-3 lists the maximum estimated impacts to air quality at the boundary of the analyzed land withdrawal area during the operations period.

Table 4-3. Maximum operations analytical period concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Carbon monoxide[e]	8-hour	10,000	68	0.68
	1-hour	40,000	550	1.4
Nitrogen dioxide[e]	Annual	100	0.12	0.12
Sulfur dioxide[e]	Annual	80	0.00078	0.00098
	24-hour	365	0.11	0.030
	3-hour	1,300	0.89	0.068
PM_{10}[e]	24-hour	150	11	7.6
$PM_{2.5}$[e]	Annual	15	0.0064	0.043
	24-hour	35	0.91	2.6
Cristobalite	Annual	10[f]	0.0021	0.021[f]

a. Appendix B describes the analysis of maximum concentrations and percent of regulatory limits.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.22097 (Table 3-5).
d. Sum of highest estimated concentrations at the accessible land withdrawal boundary regardless of direction (Appendix B contains more information). Does not include background concentrations. Table 3-2 in Chapter 3 lists the highest measured background concentrations at Yucca Mountain. The maximum concentrations would not exceed the regulatory limits after adding the highest background concentrations.
e. DOE assumed that all construction vehicles during the first 5 years of the operations period would be between model years 2006 and 2010 and would meet Tier 3 emission standards.
f. There are no regulatory limits for public exposure to cristobalite. DOE used a comparative benchmark of 10 micrograms per cubic meter (Section 4.1.2.1 and Appendix B, Section B.1).

As listed in Table 4-3, the maximum offsite concentrations of carbon monoxide, nitrogen dioxide, sulfur dioxide, and $PM_{2.5}$ would be small. The public maximally exposed individual would be exposed to less than 3 percent of the applicable regulatory limits. The maximum offsite concentration of PM_{10} could be about 7.6 percent of the applicable regulatory limits. The analysis did not take credit for standard construction dust suppression measures, which DOE would implement to further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These suppression methods would have little effect on $PM_{2.5}$ concentrations because fugitive dust is not a major source of this pollutant.

The maximum annual concentration of the ozone precursor nitrogen dioxide during the operations period would be about 0.12 percent of the regulatory limit and the annual emissions would be about 10 percent of the total estimated nitrogen dioxide emissions of 1.3 million kilograms (1,400 tons) in Nye County during 2002 (DIRS 177709-EPA 2006, all). Nitrogen dioxide forms primarily from combustion of fossil fuels from sources such as standby diesel generators, emergency diesel generators, and fossil-fueled vehicles. The Proposed Action would consume only about 2.2 percent of diesel fuel use in Clark, Nye, and Lincoln counties in 2004 and only about 0.04 percent of the gasoline (DIRS 155970-DOE 2002, p. 4-76). The other ozone precursor, volatile organic compounds, would have an estimated maximum annual emission of about 14,000 kilograms (about 30,000 pounds) during the first 5 years of the operations period. As discussed in Section 4.1.2.1, this would be significantly below the Prevention of Significant Deterioration of Air Quality emission threshold for volatile organic compounds. DOE anticipates that the impact of these pollutants on ozone formation would not cause violations of the ozone standard.

Table 4-3 also lists cristobalite concentrations at the land withdrawal area boundary. As Section 4.1.2.1 discusses for the construction period, the analysis of the operations period assumed that 28 percent of the fugitive dust releases from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The estimated exposures to cristobalite from repository operations would be approximately 0.002 microgram per cubic meter, or less than 0.03 percent of the benchmark.

Concentrations of PM_{10} would be less during the operations analytical period than during the construction analytical period due to a decrease in surface disturbance and a reduction in concrete batch plant operations. Concentrations of cristobalite also would decrease during the operations period even though the amount of subsurface excavation and the size of the excavated rock pile would increase. Concentrations of gaseous criteria pollutants would increase during the first 5 years of the operations period over those of the construction period due to vehicle emissions from construction activities and repository operations and to emissions from diesel generators and boilers.

No air quality impacts would result from facilities outside the land withdrawal area during the operations analytical period. The training facility and marshalling yard would not be significant sources of criteria pollutants. The amount of fuel that vehicles would use at the facilities would not be large. Standard dust suppression methods would mitigate potential fugitive dust (PM_{10}) emissions at the marshalling yard.

4.1.2.3 Impacts to Air Quality from Monitoring

This section describes potential nonradiological air quality impacts during the monitoring analytical period for the proposed repository. For analytical purposes, this period would begin with the emplacement of the final waste package and continue for 50 years after the end of the operations analytical period. Activities during this period would include maintenance of active ventilation of the repository for as long as 50 years, remote inspection of waste packages, retrieval of waste packages to correct detected problems (if necessary), and continuing investigations to support predictions of postclosure repository performance. Section 4.2 discusses air quality impacts of the retrieval contingency.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities. During this period, air pollutant emissions would decrease. Surface construction, subsurface excavation, and subsurface emplacement activities would be complete, resulting in a lower level of emissions in comparison to previous periods. Pollutant concentrations at the analyzed land withdrawal area boundary would be substantially lower than those in Table 4-3.

No air quality impacts would result from facilities outside the land withdrawal area during the monitoring period. There would be significantly less activity at offsite facilities such as the training facility and marshalling yard, so they would not be significant sources of criteria pollutants.

4.1.2.4 Impacts to Air Quality from Closure

This section describes potential nonradiological air quality impacts during the closure analytical period for the proposed repository. This period, which would last 10 years and would overlap the last 10 years of the monitoring period, would begin on receipt of a license amendment to close the repository. Activities would include closure of subsurface repository facilities, backfilling, sealing of subsurface-to-surface openings, decommissioning and demolition of surface facilities, construction of monuments to mark the site, and reclamation of remaining disturbed lands. These activities would result in the following air emissions during this period:

- Fugitive dust (PM_{10}) emissions from the handling, processing, and transfer of backfill material to the subsurface;
- Fugitive dust (PM_{10}) releases from demolition of buildings, removal of debris, and land reclamation;
- Cristobalite releases from the handling and storage of excavated rock;
- Particulate matter (PM_{10}) from the concrete batch plants; and
- Gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, and sulfur dioxide) and particulate matter ($PM_{2.5}$) from fuel consumption.

Table 4-4 lists the maximum estimated impacts to air quality at the boundary of the analyzed land withdrawal area during the closure period.

Gaseous criteria pollutants would result primarily from vehicle exhaust. During the closure period, the maximum concentrations of carbon monoxide, nitrogen dioxide, sulfur dioxide, and $PM_{2.5}$ would be small. Concentrations of carbon monoxide, nitrogen dioxide, and sulfur dioxide would be less than 0.1 percent of the regulatory limits, and concentrations of $PM_{2.5}$ would be less then 1 percent of the regulatory limits. The maximum offsite concentration of PM_{10} would be less than 20 percent of the regulatory limit. The analysis did not take credit for standard construction dust suppression measures, which DOE would implement and would further lower projected PM_{10} concentrations by reduction of fugitive dust from surface-disturbing activities. These suppression methods would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of that pollutant.

As with the construction period (Section 4.1.2.1), the analysis of the closure analytical period assumed that 28 percent of the fugitive dust releases from the excavated rock pile would be cristobalite. Table 4-4 lists estimated cristobalite concentrations for the maximally exposed offsite individual during closure. As noted in Section 4.1.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The estimated exposures to cristobalite from repository closure would be approximately 0.0026 microgram per cubic meter, or less than 0.03 percent of the benchmark.

Table 4-4. Maximum closure analytical period concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Carbon monoxide[e]	8-hour	10,000	2.9	0.029
	1-hour	40,000	24	0.059
Nitrogen dioxide[e]	Annual	100	0.023	0.023
Sulfur dioxide[e]	Annual	80	0.000045	0.000056
	24-hour	365	0.0065	0.0018
	3-hour	1,300	0.052	0.0040
PM_{10}[e]	24-hour	150	29	19
$PM_{2.5}$[e]	Annual	15	0.0013	0.0090
	24-hour	35	0.19	0.55
Cristobalite	Annual	10[f]	0.0026	0.026[f]

a. Appendix B describes the analysis of maximum concentrations and percent of regulatory limits.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.22097 (Table 3-5).
d. Sum of highest estimated concentrations at the accessible land withdrawal boundary regardless of direction (Appendix B contains more information). Does not include background concentrations. Table 3-2 in Chapter 3 lists the highest measured background concentrations at Yucca Mountain. The maximum concentrations would not exceed the regulatory limits after adding the highest background concentrations.
e. DOE assumed that all construction vehicles would be between model years 2006 and 2010 and would meet Tier 3 emission standards.
f. There are no regulatory limits for public exposure to cristobalite. DOE used a comparative benchmark of 10 micrograms per cubic meter (Section 4.1.2.1 and Appendix B, Section B.1).

4.1.2.5 Total Impacts to Air Quality from All Periods

The nonradiological air quality analysis examined concentrations of criteria pollutants at the boundary of the land withdrawal area in comparison with the National Ambient Air Quality Standards for periods ranging from 1 hour to an annual average concentration of pollutant. The analysis calculated the maximum project impact from the highest unit release concentrations of the American Meteorological Society/Environmental Protection Agency Regulatory Model from the years modeled (Appendix B describes the analysis). The highest concentrations of all criteria pollutants except PM_{10} would be less than 3 percent of applicable standards in all cases. The highest concentrations of PM_{10} from activities in the land withdrawal area could be 40 percent of the 24-hour limit during the construction period.

4.1.3 IMPACTS TO HYDROLOGY

This section summarizes and incorporates by reference applicable portions of Section 4.1.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-19 to 4-31). In addition, it addresses potential impacts that could change as a result of modifications to repository design and operational plans.

This section describes potential environmental impacts to the hydrology of the Yucca Mountain region from construction, operations and monitoring, and eventual closure of a repository at Yucca Mountain. It identifies and evaluates potential surface-water and groundwater impacts separately, as DOE did in the Yucca Mountain FEIS. The region of influence and the assessment attributes, or criteria, are the same as those in the FEIS. Chapter 5 discusses postclosure impacts from the long-term performance of the repository.

The attributes DOE used to assess surface-water impacts were the potential for the introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to worsen any of these conditions. The region of influence for surface-water impacts included construction and operations sites that would be susceptible to erosion, areas that permanent changes in surface-water flow could affect near these sites, and downstream areas that eroded soil or potential spills of contaminants would affect. The evaluation of surface-water impacts is very similar to that presented in the Yucca Mountain FEIS, but is modified to address a slightly larger amount of land disturbance, two additional wastewater evaporation ponds, and a tentative facility layout that more specifically incorporates storm water detention ponds into its design.

The attributes DOE used to assess groundwater impacts included the potential to change infiltration rates that could affect groundwater, the potential for the introduction of contaminants, the availability of groundwater for project use, and the potential for such use to affect other groundwater users. The region of influence for the groundwater analysis included aquifers under the areas of construction and operations, aquifers from which DOE could obtain water, and downstream aquifers that repository uses could affect. The evaluation of groundwater impacts is also very similar to that in the Yucca Mountain FEIS, but addresses changes to the estimated water demand from the Proposed Action.

4.1.3.1 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent, year-around surface-water bodies in the Yucca Mountain region of influence, and instances when precipitation and runoff are sufficient to generate flowing water in drainage channels are infrequent and short-lived. Nevertheless, the manner in which the Proposed Action would accommodate or otherwise affect these infrequent conditions determines potential impacts to surface water. The primary impact areas for the Proposed Action are the following:

- Discharges of water to the surface,
- Introduction of contaminants that could spread to surface water,
- Changes to surface-water runoff or infiltration rates, and
- Alteration of natural surface-water drainage, which would include effects to floodplains (or flood zones).

4.1.3.1.1 *Discharge of Water to the Surface*

DOE would pump groundwater at the site and store it in tanks to support the following uses: fire protection, deionized water, potable water, cooling tower makeup, and makeup to other water systems. There would be few discharges of water. DOE would pipe sanitary sewage to septic tank and leach field systems, so there would be no production of surface water, and the processes that routinely produced other wastewater would involve discharges to one of four or possibly five lined evaporation ponds as follows:

1. South Portal evaporation pond for dust control water returned from subsurface development,

2. North Construction Portal evaporation pond for dust control water returned from subsurface development,

3. North Portal evaporation pond for process wastewater,

4. Central operations area evaporation pond for process wastewater, and

5. Small evaporation pond (possibly) for concrete batch plant wastewater.

DOE would provide water to the subsurface during the development of the underground areas of the proposed repository. The Department would collect excess water from dust suppression applications and water that percolated into the repository drifts, if any, and send the water to evaporation ponds at the South Portal development area or the North Construction Portal. The South Portal evaporation pond, which would have an area of about 0.0024 square kilometer (0.6 acre), would have double polyvinyl chloride liners and a leak detection system. The evaporation pond at the North Construction Portal would be of similar size and construction

The North Portal evaporation pond, which DOE would locate adjacent to the facilities in the central operations area just outside the geologic repository operations area, would receive wastewater in the form of cooling tower blowdown and water softener regeneration solutions from facility heating and air conditioning systems. DOE would send water from floor and equipment drains of the surface facilities and the emplacement side of the subsurface to the North Portal evaporation pond after verification that it was not contaminated. (The Department would manage contaminated water as low-level radioactive waste.) The North Portal evaporation pond, which would have an area of about 0.024 square kilometer (6 acres), would have, at a minimum, a polyvinyl chloride liner. The fourth evaporation pond, also in the central operations area, would receive process water from two oil-water separators and superchlorinated water from maintenance of the drinking water system.

Table 4-5 lists the quantities of water discharged to the North Construction Portal and the South Portal ponds, which would be similar to those in the Yucca Mountain FEIS. As listed in the table, the estimates include two phases of underground development (called “heavy” and “light” only in relation to each other) after completion of the primary surface construction period. The estimated quantity of water DOE would discharge to the North Portal evaporation pond would be no different than that in the Yucca Mountain FEIS; that is, about 34,000 cubic meters (9 million gallons) per year for the operations period.

Table 4-5. Combined annual water discharges to the North Construction Portal and the South Portal evaporation ponds.

Period	Duration[a] (years)	Discharge[b] (cubic meters)
Construction	5	4,300
Operations		
Heavy development	8	6,400
Light development	up to 17	2,800

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Discharge to this pond would occur only during subsurface development activities.

b. Source: DIRS 181232-Fitzpatrick-Maul 2007, all. Estimated discharge volumes would be 13 percent of the process water sent to the subsurface based on Exploratory Studies Facility construction experience.

With proper maintenance, the lined evaporation ponds should remain intact and produce no adverse effects at the repository site. DOE would build another, much smaller lined evaporation pond, as appropriate, in the general area of the concrete batch plants to facilitate the collection and management of equipment rinse water. As an alternative, DOE could divert wastewater from the batch plants to the South Portal evaporation pond.

The water that DOE would use for dust suppression is a type of discharge. DOE studied dust suppression during characterization activities at Yucca Mountain because of the concern that any water added to the surface or subsurface could have effects on the subsurface area of the proposed repository. The amount of water used for dust suppression would result in neither runoff nor infiltration. DOE would establish controls as necessary to ensure that dust suppression would not involve unnecessary quantities of water.

Repository facility operations would involve other uses of water, but they would have little, if any, potential to generate surface water. DOE would collect wastewater from the Wet Handling Facility pool, decontamination stations, surface facility drain system, and various equipment drains and, if sampling of the collection tanks and sumps indicated the presence of contamination, would manage that water as low-level radioactive waste.

Discharges to the surface during the monitoring and closure periods would be similar to but less than those for the construction and operations periods. The evaporation ponds would not be in use, but other manmade sources of surface water would be similar—water storage tanks would be in use, there would be sanitary sewage, and dust suppression would occur as necessary.

4.1.3.1.2 *Potential for Contaminant Spread to Surface Water*

There would be no permanently piped, routine liquid effluents from surface or subsurface facilities to surface water or drainage channels. The potential for contaminants to reach surface water or surface drainages would be limited to the simultaneous occurrence of a spill or leak and heavy precipitation or snowmelt. Because there are no natural perennial surface waters in the Yucca Mountain region of influence and no readily available sources of contamination, it would take both events to result in a surface spread of contamination.

Potential contaminants during construction would consist mostly of fuels (diesel, propane, and gasoline) and lubricants (oils and grease) for equipment. Fuel storage tanks would be in place early in the construction period, and DOE would construct or install them with appropriate secondary containment (consistent with 40 CFR Part 112). Other potential contaminants, such as paints, solvents, strippers, and concrete additives, also would be in use during construction, but in smaller quantities and much smaller containers. Such materials would probably be in 210-liter (55-gallon) or smaller drums and containers. DOE would minimize the potential for spills and, if they occurred, would minimize contamination by adherence to its *Spill Prevention, Control, and Countermeasures Plan for Site Activities* (DIRS 172055-DOE 2004, all), which it would update for repository construction. The plan would describe actions DOE would take to prevent, control, and remediate spills, and the reporting requirements for a spill or release.

DOE management of the spent nuclear fuel and high-level radioactive waste at the proposed repository would start at the beginning of the operations period. After acceptance at the site and before emplacement in the subsurface facility, DOE would keep these materials in the restricted area of the geologic repository operations area. Spent nuclear fuel and high-level radioactive waste, mostly in canisters, would also be in transportation casks, aging overpacks, transfer casks, or waste packages. These containers would minimize the potential for releases and would shield people, to a large extent, from radiation exposure during the transfer of spent nuclear fuel and high-level radioactive waste between facilities in the geologic repository operations area. In the waste handling buildings, facility system and component design would reduce the likelihood of inadvertent releases to the environment; for example, drain lines would lead to internal tanks or catchments, air emissions would be filtered, and the pool of the Wet Handling Facility would have a stainless-steel liner and leak detection.

DOE would use fuels and lubricants during the operations period for equipment operation and maintenance, and would manage them in the manner described above for the construction period. The Department would use other chemicals and hazardous materials during this period, particularly in the Low-Level Waste Facility, which would use sodium hydroxide and sulfuric acid in treatment processes. In addition, activities during this period would require relatively small quantities of cleaning solvent. With the exception of fuels, which would be managed in outdoor tanks with secondary containment, DOE would use and store these hazardous materials inside buildings, and would manage all of the materials in accordance with applicable environmental, health, and safety standards and the Spill Prevention, Control, and Countermeasures Plan. Therefore, the potential for spills and leaks of contaminants would be small and, if they occurred, there would be little potential for contaminants to spread far beyond the point of release.

DOE would manage liquid low-level radioactive waste from the waste handling facilities in, or adjacent to, the Low-level Waste Facility and would maintain the waste in monitored containers. It would maintain and move hazardous and mixed wastes in closed containers before shipping them to a permitted treatment facility. These conditions would minimize the potential for spills and releases.

There would be a decrease in general activities at the site after emplacement was complete and the monitoring period began. There would be a corresponding decrease in the potential for spills and releases from routine activities during the operations period. However, decontamination actions that would follow the operations or monitoring period could present other risks due to the use of decontamination solutions and the start of new work. DOE would continue to implement plans and controls to limit the potential for contaminant spread by surface water. In addition, DOE would perform environmental monitoring during the operations and monitoring periods to identify the presence of contaminants that could indicate a release.

In addition to measures to reduce the potential for spills or releases to reach or be spread by surface water, DOE would take measures to prevent runoff and flood waters from reaching areas where they could contact contaminated surfaces or cause releases of hazardous materials. The Department would protect surface facilities that were important to safety (basically those in the restricted area of the geologic repository operations area) against the probable maximum flood by building the structures above the corresponding flood elevation or by using engineered barriers such as dikes or drainage channels. It would build other facilities to withstand a 100-year flood, which is consistent with common industrial practice and DOE policy. Inundation levels for any flood level, even the probable maximum flood, would present no hazard to the subsurface facilities because the portals would be at higher elevations than the flood-prone areas. The construction of storm water retention and detention ponds in appropriate areas would address potential flooding and storm water pollution issues. DOE would augment the effectiveness of the storm water ponds, as necessary, by providing diversion channels to move runoff away from surface facilities and aging pads.

The closure period would include further reductions in the potential for contaminant spread, but DOE would continue to implement engineering controls, monitoring, and release-response requirements to ensure that the potential was minimal, which would include during the demolition of surface facilities when water use for dust control would be likely to increase.

4.1.3.1.3 *Potential for Changes to Surface-Water Runoff or Infiltration Rates*

Areas disturbed due to the construction of surface facilities at Yucca Mountain probably would experience changes in the rates of infiltration. Areas where infiltration rates decreased would experience a corresponding increase in surface-water runoff. The Proposed Action could disturb as much as 9 square kilometers (2,200 acres) of land, which would include about 2.4 square kilometers (600 acres) already disturbed as a result of Yucca Mountain characterization activities. In this area of disturbance, areas where soil was loosened or scraped away from fractured rock likely would experience increased infiltration rates, and covered or compacted surface areas probably would experience decreased infiltration rates. Most land disturbed during construction would fit into the latter scenario that involved compaction of natural surfaces or the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings.

Overall, there would be less infiltration and more runoff from the site. However, DOE expects the change in the amount of runoff that would reach the drainage channels to be small, with small impacts, for two reasons. First, the Department would build the surface geologic repository operations area (which would include the balance of plant area, where most of the facilities and built-up areas would be) with integral storm water detention ponds. All of the runoff from this surface area would be controlled in this manner and, as a result, existing drainage channels outside of this surface area would not be adversely affected by runoff increases. The second reason applies to the relative scale of the disturbed area and its location. The storm water detention ponds would minimize the most serious concern from increased runoff from built-up areas, so any other increases or decreases in runoff would involve a relatively small amount of the natural drainage. For example, the natural drainage area of Drill Hole Wash, which includes the Midway Valley drainage, represents the area the Proposed Action would affect the most. About 4.8 square kilometers (1,200 acres) of land would be disturbed in and adjacent to the geologic repository operations area. This disturbed area is about 12 percent of the 40 square kilometers (9,900 acres) that make up the drainage area of Drill Hole Wash by the time it reaches Fortymile Wash. On a larger scale, most if not all of the total land disturbance of 9 square kilometers (2,200 acres) would be in the natural drainage area for Fortymile Wash. The disturbed area would be approximately 1 percent of the Fortymile Wash drainage, which is about 820 square kilometers (200,000 acres) where the wash leaves the Nevada Test Site near U.S. Highway 95 (DIRS 169734-BSC 2004, Table 7-3). Further, because of the isolated location of these drainage channels, there are no downstream facilities that the minor changes in runoff could reasonably affect.

The Proposed Action would disturb no additional land during the monitoring period and, therefore, there would be no adverse impacts to runoff rates. Reclamation of previously disturbed land would restore preconstruction runoff rates.

Closure of the repository would involve only previously disturbed land. Removal of structures and impermeable surfaces coupled with reclamation efforts would help restore infiltration and runoff rates to near-predisturbance conditions. DOE would construct monuments to provide long-term markers for the site such that their locations would be impervious to infiltration, but the affected areas would be small.

4.1.3.1.4 *Potential for Altering Natural Surface-Water Drainage*

Construction could involve the placement of structures, facilities, or roadways in or over drainage channels or their associated floodplains (or flood zones). These actions could affect Fortymile, Midway Valley (Sever), Drill Hole, and Busted Butte (Dune) Washes and their associated floodplains. DOE would control surface-water drainage in these washes with diversion channels, culverts, storm water detention ponds, or similar drainage control measures.

Pursuant to Executive Order 11988, *Floodplain Management*, and its implementing regulation at 10 CFR Part 1022, DOE must, when conducting activities in a floodplain, take action to reduce the risk of flood damage; minimize the impacts of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. Appendix C contains a floodplain/wetlands assessment that describes the actions that DOE could take. The analysis indicated that consequences of DOE actions in or near the floodplains of the four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains.

The closure period would involve no actions that would alter natural drainage beyond those affected in prior periods. DOE would grade areas where it demolished or removed facilities to match the natural topography to the extent practicable. The Department would not build monuments where they would alter important drainage channels or patterns.

4.1.3.2 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

The groundwater-related impacts of primary concern are as follows:

- The potential for changes in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect performance of waste containment in the repository, or decrease the amount of recharge to the aquifer;
- The potential for migration of contaminants from the surface to reach the unsaturated zone or aquifers; and
- The potential for project water demands to deplete groundwater resources to an extent that could affect downgradient groundwater use.

4.1.3.2.1 *Infiltration Rate Changes*

Surface-disturbing activities would alter infiltration rates in and around the geologic repository operations area, as described in Section 4.1.3.1. Because impermeable surfaces and compacted ground would cover much of the disturbed land, DOE anticipates a net decrease in infiltration and a corresponding increase in runoff over the disturbed area. In the dry, semiarid environment of Yucca Mountain, much of the total infiltration occurs in areas of higher elevation, areas with thin or no soil cover, or in the upper reaches of washes. The amount of projected recharge along Fortymile Wash is very small in comparison with the recharge of the aquifers from farther north. The increased runoff from the disturbed surface area from the Proposed Action could cause more water to reach Fortymile Wash, and the storm water detention ponds would represent new areas of temporary water accumulation. As a result, additional infiltration could occur in these locations in comparison with existing conditions. However, the areas potentially subject to increased infiltration would be localized and small in comparison with infiltration that occurred over the entire Fortymile Wash drainage area. Any increase in infiltration would be unlikely to affect overall groundwater recharge or flow patterns.

Surface disturbance along the crest of Yucca Mountain and on the steeper slopes above the proposed repository could present different scenarios for infiltration rate changes because the depth of unconsolidated material (that is, soil and gravel) in these areas is generally thin, and there would be a higher probability that disturbance could expose fractured bedrock where precipitation and runoff could enter cracks and crevices and more readily reach deep portions of the unsaturated zone. Ventilation shafts to the subsurface area and access roads to those locations are the primary examples of surface disturbances that would occur in the upper areas of Yucca Mountain. The amount of disturbed land in these areas would be small in comparison with the undisturbed area, and any net change in infiltration would be small.

Subsurface activities could change groundwater recharge rates, primarily due to the amount of water that DOE would pump to the subsurface for dust suppression and tunnel boring during development activities. This potential for increased recharge would be offset by measures to collect and remove accumulating water back to the surface (to the North Construction Portal and the South Portal evaporation ponds), by removal of wet excavated rock to the surface, and by keeping the work areas ventilated, which would promote evaporation of the remaining water. During the excavation of the Exploratory Studies Facility, DOE tracked water introduced to the subsurface because water that remained in the subsurface could affect DOE’s understanding of postclosure performance of the proposed repository. Tracking of the use of water in the subsurface would continue under the Proposed Action, and DOE anticipates that changes in recharge through Yucca Mountain would have small impacts to the groundwater system.

No additional land disturbance would occur during the monitoring and closure periods, so further effects on infiltration rates would be unlikely. Soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. Monuments that DOE constructed to provide long-lasting markers for the site would probably result in impermeable locations, but they would be small in relation to the surrounding areas.

4.1.3.2.2 *Potential for Contaminant Migration to Groundwater*

Section 4.1.3.1 discusses the types of contaminants that DOE could use at the proposed repository site and the possibility of spills or releases of these materials to the environment. Adherence to regulatory requirements and a Spill Prevention, Control, and Countermeasures Plan (Section 4.1.3.1) would minimize the potential for spills or releases to occur and would require appropriate responses to clean up or otherwise abate any such incident. Natural conditions, which include depth to groundwater, thickness of alluvium in most areas, and arid environment, would help ensure that significant contaminant migration did not occur before DOE could take action. Section 4.1.8 discusses the potential for onsite accidents that could involve releases of contaminants. Chapter 5 discusses the postclosure release of contaminants from the waste packages in the repository.

4.1.3.2.3 *Groundwater Resources*

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction period and early in the operations period, when DOE would need water for surface soil compaction and dust suppression as well as subsurface development. The evaluation of impacts for this Repository SEIS addressed potential impacts from this water demand only during these heavy-use periods. Table 4-6 summarizes water demands during these two periods of heavy water use. Water demand during the monitoring and closure periods would be lower and of less concern and would be expected to remain as presented in the Yucca Mountain FEIS.

Table 4-6. Annual water demand for construction and operations.

Period	Duration[a] (years)	Water demand[b] (acre-feet per year)[c]
Construction	5	220 to 430
Operations		
Emplacement plus continued underground development and surface construction[d]	5	180 to 260
Emplacement and continued underground development	up to 25	100 to 160
Emplacement	up to 20	62

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Several of the project periods are flexible in the number of years they could last. In such cases, values are "up to" with a breakout representative of the maximum length and most conservative high water demand expected. For example, DOE expects the operations period to last up to 50 years; within that period, subsurface development could last up to a total of 30 years. If development took less time, the last phase of emplacement could be longer than 20 years, so the total would still be 50.
b. Source: DIRS 181232 -Fitzpatrick-Maul 2007, all.
c. This table lists acre-feet because of common statutory and public use of this unit of measure for groundwater resources.
d. Although the analysis assumed that the formal construction period would be 5 years, some construction activities could extend into the operations period (Chapter 2, Table 2-1).

Figure 4-1 shows annual water demands during construction and the first few years of the operations period. It shows water demand during this period because it would be the period of greatest fluctuation and would include the year of peak water demand.

Water demand would be highest during the initial construction period and would range from about 270,000 to 530,000 cubic meters (220 to 430 acre-feet) per year (Table 4-6 and Figure 4-1). During the first 5 years of the operations period, construction of surface and subsurface facilities would occur along with emplacement of spent nuclear fuel and high-level radioactive waste; water demand would range from about 220,000 to 320,000 cubic meters (180 to 260 acre-feet) per year. Other than a slight increase at the beginning of this 5-year period, annual water demand would decline for each successive year of operations. Subsurface development could continue for up to the next 25 years, but water demand would generally continue to decline and would level off at about 125,000 cubic meters (100 acre-feet) per year. After the development of the subsurface area was complete, the primary operations would consist of waste receipt and emplacement. Water demand would drop to about 77,000 cubic meters (62 acre-feet) per year during this period.

DOE would meet water demand by pumping from existing wells, and possibly one new well, in the Jackass Flats hydrographic area. The new well, if installed, would support operations at Gate 510. Table 4-6 and Figure 4-1 do not include Nevada Test Site activities in this area, which would require

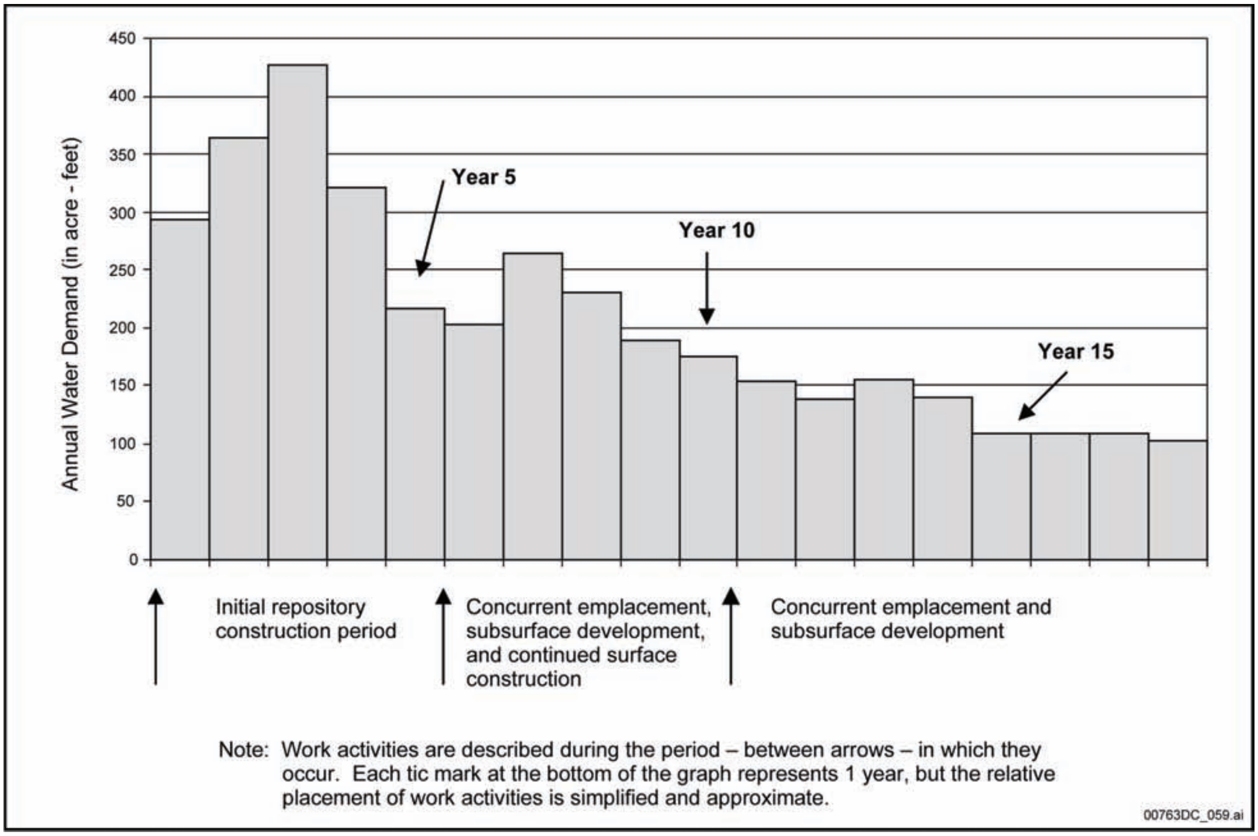


Figure 4-1. Annual water demand during the construction period and the initial phases of operations.

groundwater during the same period. During the 7-year period from 2000 to 2006, the average Nevada Test Site water withdrawal from this hydrographic area has been about 83,000 cubic meters (67 acre-feet) per year (DIRS 181232 -Fitzpatrick-Maul 2007, all). In a 2002 analysis, the Test Site indicated there were no planned expansions of existing operations that would affect water use, but potential future programs could involve additional water use (DIRS 162638-DOE 2002, pp. 4-18 and 4-19). The following evaluation assumed that this recent use represents a reasonable estimate of Nevada Test Site water demand from Jackass Flats, at least in the near term (5 to 10 years). However, DOE recognizes that Test Site demand could increase in the future. As shown in Table 4-6 and Figure 4-1, water demand for the Proposed Action would decrease over time. This additional water demand for the Nevada Test Site is part of the cumulative impacts analysis in Chapter 8 of this Repository SEIS. At least for the peak water demand years of the Proposed Action, the estimated additional water demand for Nevada Test Site activities would be 83,000 cubic meters (67 acre-feet).

DOE used the three approaches it used in the Yucca Mountain FEIS to evaluate potential impacts of water demand on groundwater resources:

- Comparison with impacts observed or measured during past water withdrawals,
- Comparison of the proposed demand with estimates of perennial yield of the aquifer, and
- Groundwater modeling efforts to assess changes the proposed demand would have on groundwater elevations and flow patterns.

The following paragraphs address potential impacts from the construction and operations periods, when water demand would be the highest. Impacts from water demand during the monitoring period would be small in comparison, except during the first 3 years, when they would be moderate. Impacts during the closure period would be small in comparison.

4.1.3.2.4 *Comparison with Impacts from Past Water Withdrawals*

The peak water demand would be about 610,000 cubic meters (500 acre-feet) per year [that is, 530,000 cubic meters (430 acre-feet) from the Proposed Action from Table 4-6, plus 83,000 cubic meters (67 acre-feet) from Nevada Test Site needs]. This demand would be 25 percent higher than the peak withdrawal of about 490,000 cubic meters (400 acre-feet) during the past 15 years from the Jackass Flats area (Chapter 3, Section 3.1.4.2.2; DIRS 155970-DOE 2002, Table 3-16, p. 3-66). However, this peak demand would occur for only a single year and the average annual water demand over the 5-year construction period would be about 480,000 cubic meters (390 acre-feet) with the Nevada Test Site needs. This demand is quite similar to the groundwater withdrawals during the busier period of the Yucca Mountain site characterization activities. During the next 5-year period, when underground development and some surface construction would occur simultaneously with emplacement operations, annual water demand would average about 350,000 cubic meters (280 acre-feet). Based on the past history of groundwater withdrawals from the Jackass Flats hydrographic area and the corresponding minor changes in groundwater elevations (Chapter 3, Table 3-5), the proposed water demand amounts would be unlikely to adversely affect the stability of the water table in the area.

4.1.3.2.5 *Comparison with Estimates of Groundwater Perennial Yield*

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depletion of the reservoir. As discussed in Chapter 3, Section 3.1.4.2.1, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet). The source of the low end of this range is an estimate of the annual groundwater recharge that occurs in the Jackass Flats hydrographic area, so it includes no underflow that enters the area from upgradient groundwater basins. This low estimate can be further reduced, to be more conservative, by attributing 720,000 cubic meters (580 acre-feet) to the western two-thirds of the Jackass Flats hydrographic area (where the Proposed Action would withdraw water) and 370,000 cubic meters (300 acre-feet) to the eastern one-third. This last reduction accommodates the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. These yield values (from the low estimates, associated only with local recharge, to the highest estimate, which is more than 4 times greater) occur not only in groundwater studies but also in the Nevada State Engineer's rulings that address water appropriation requests for Jackass Flats groundwater (DIRS 105034-Turnipseed 1992, pp. 9 and 12).

The peak annual demand of 530,000 cubic meters (430 acre-feet) would be below the lowest estimates of the perennial yield of the Jackass Flats area, even if that is the amount attributable to the western two-thirds of the area. With the addition of water demand for the Nevada Test Site, the peak annual demand would still be below the lowest estimate of yield from the western two-thirds of the area; that is, a demand of 610,000 cubic meters (500 acre-feet) in comparison with the lowest estimate of perennial yield of 720,000 cubic meters (580 acre-feet). A comparison of the peak annual water demand (with the demand from Test Site activities) with the highest estimate of the Jackass Flats perennial yield indicated only 13 percent of the highest value.

Based on these comparisons of the proposed water demand with estimates of the perennial yield of the Jackass Flats area, DOE has concluded that the Proposed Action would not deplete the groundwater reservoir. The Department recognizes that annual recharge can change significantly from year to year, depending on the area weather patterns. For the peak year, water demand could exceed groundwater recharge in the western two-thirds of the Jackass Flats hydrographic area. However, water demand at that high level and similar levels would be relatively short-term. If water demand exceeded local recharge for a few years (longer durations would be unlikely based on the estimates of average annual recharge), there could be some shifting of the general flow patterns in the Jackass Flats area. Shifts in flow patterns would be small because the peak annual water demand would be a small portion of the highest estimate of perennial yield, 4.9 million cubic meters (4,000 acre-feet), which would include underflow from upgradient groundwater basins.

As noted in the Yucca Mountain FEIS, the heaviest water demand in the region of influence for the Proposed Action would be in the Amargosa Desert. The water demand for the Proposed Action would, to some extent, decrease the availability of water in the downgradient area because it would reduce the long-term underflow that reached the Amargosa Desert. However, the peak annual water demand of 610,000 cubic meters (500 acre-feet) for proposed repository and Nevada Test Site activities in Jackass Flats would be small (about 4 percent) in comparison with the average annual withdrawal of 16 million cubic meters (13,000 acre-feet) in the Amargosa Desert between 2000 to 2004 (Chapter 3, Table 3-4) for activities other than the Proposed Action or the Test Site. The demand of repository and Test Site activities in Jackass Flats would be an even smaller fraction of the perennial yield of 30 million to 42 million cubic meters (24,000 to 34,000 acre-feet) in the Amargosa Desert.

Comparisons between water demand and estimates of perennial yield (Chapter 3, Table 3-4) must recognize the wide range of perennial yield estimates for the hydrographic areas of Jackass Flats and Amargosa Desert as well as the adjacent hydrographic areas. One estimate of perennial yield in State of Nevada documentation is 30 million cubic meters (24,000 acre-feet) for the combined area of Jackass Flats, Amargosa Desert, Rock Valley, Buckboard Mesa, and Crater Flat (DIRS 176600-Converse Consultants 2005, p. 99), as opposed to the 30-million-cubic-meter estimate just for Amargosa Desert. The state uses estimates of perennial yield as a tool (with other considerations) in the management of groundwater resources and evaluation of requests for groundwater appropriations. The other side of the evaluation of potential impacts on groundwater resources is that, independent of the physical availability of water, the groundwater of the Amargosa Desert is over-appropriated in comparison with many estimates of perennial yield. However, as noted in Section 3.1.4.2.1, the amount of water actually withdrawn each year from the Amargosa Desert hydrographic area has averaged only about half of the total appropriations in recent years.

4.1.3.2.6 *Modeled Effects on Groundwater Elevations and Flow Patterns*

This section summarizes the two modeling efforts described in the Yucca Mountain FEIS, one by Thiel Engineering Consultants for DOE (DIRS 145966-CRWMS M&O 2000, all) and the other by the U.S. Geological Survey (DIRS 145962-Tucci and Faunt 1999, all). DOE used the results of these analyses to estimate effects the Proposed Action could have on groundwater elevations and flow patterns. Both modeling efforts generated baseline groundwater conditions from historical water withdrawals from the Jackass Flats area, then generated future groundwater conditions with the assumption of an additional water demand of 530,000 cubic meters (430 acre-feet) per year for the Proposed Action. As indicated in Figure 4-1, the water demand DOE evaluated for the Proposed Action would peak for only 1 year at the model-assumed withdrawal rate. Because the model conclusions used a long-term withdrawal rate of 530,000 cubic meters per year, those conclusions are very conservative. Over the first 10 years of the Proposed Action when the peak annual demand would occur, the average annual water demand would be only 330,000 cubic meters (270 acre-feet). Over the life of the Proposed Action, the average annual water demand would be much less. Results from the modeling efforts indicated there would be groundwater elevation differences attributable to the Proposed Action, as follows:

- The Thiel Engineering Consultants study predicted a water elevation decrease of up to 3 meters (10 feet) within about 1 kilometer (0.6 mile) of the Yucca Mountain production wells. The U.S. Geological Survey model predicted a similar water level decrease of less than 2 meters (6.6 feet) at distances a few kilometers from the production wells.

- The models predicted water elevation decreases at the town of Amargosa Valley that ranged from less than 0.4 meter (1.2 feet) to 1.1 meters (3.6 feet). [In this case, the predictions were for groundwater roughly at the junction of U.S. Highway 95 and Nevada State Route 373, about 13 kilometers (8 miles) south of well J-12.]

- The Thiel Engineering Consultants study estimated a reduction in the underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area of about 160,000 cubic meters (130 acre-feet) per year after 100 years of pumping. The U.S. Geological Survey effort estimated an underflow reduction of 180,000 cubic meters (150 acre-feet) per year at steady-state conditions.

The Thiel Engineering Consultants modeling effort looked at numerous locations and pumping scenarios throughout the region and concluded in all areas of the Amargosa Desert that groundwater elevation decreases attributable to the Proposed Action, though possibly moderate by themselves, would be minor in comparison with decreases without the Proposed Action. Both modeling efforts assumed a conservatively high value for the water demand of the Proposed Action, so the predicted impacts, even though moderate in scale, were conservatively high.

4.1.3.3 Summary of Impacts to Hydrology

The following summarize the conclusions of the evaluations in this section:

- Repository construction and operations would result in minor changes to runoff and infiltration rates.

- The potential for flooding at the repository that could cause damage of concern would be extremely small.

- The highest annual water demand for the Proposed Action would be below the Nevada State Engineer’s ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats hydrographic area, including the lowest estimated value of perennial yield [720,000 cubic meters (580 acre-feet)] for the western two-thirds of this hydrographic area. The water demand for the Proposed Action, coupled with that projected for Nevada Test Site activities in Jackass Flats, would still be below the lowest estimated value of perennial yield for the western two-thirds of the hydrographic area.

- The Proposed Action would withdraw groundwater that would otherwise move into aquifers of the Amargosa Desert, but the combined water demand for the repository and Nevada Test Site activities in Jackass Flats would have, at most, small impacts on the availability of groundwater in the Amargosa Desert area in comparison with the quantities of water already being withdrawn there.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The region of influence for biological resources and soils in this Repository SEIS is the area that contains all potential surface disturbances that would result from the Proposed Action plus additional areas to evaluate local animal populations, roughly equivalent in size to the analyzed land withdrawal area that DOE assessed in the Yucca Mountain FEIS, as well as land DOE proposes for an access road from U.S. Highway 95 and land where DOE could construct offsite facilities. The Department has reanalyzed impacts to biological resources and soils for this Repository SEIS based on the modified design that Chapter 2 describes. The evaluation of impacts to biological resources and soils considered the potential for effects to vegetation and wildlife, which included special-status species of plants and animals and their habitats; jurisdictional waters of the United States, which included wetlands; riparian areas; and soil resources. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources would be small because plant and animal species in the Yucca Mountain region are typical of the Mojave and Great Basin deserts and generally are common throughout those areas. The removal of vegetation from the area that DOE would require for construction and operation of the repository and the small impacts to some wildlife species from disturbance or loss of individuals or habitat would not affect regional biodiversity and ecosystem function.

4.1.4.1 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

As discussed in Section 4.1.7 of this Repository SEIS, routine releases of radioactive materials from the repository during its operation would consist mainly of naturally occurring radon-222 and its decay products. These releases would result in doses to plants and animals around the repository that would be lower than the International Atomic Energy Agency thresholds for detrimental effects to radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53). No detectable impacts to surface biological resources would occur as a result of normal releases of radioactive materials from the repository; therefore, the following sections do not consider these releases.

4.1.4.1.1 *Impacts to Vegetation*

The construction of surface facilities and the disposition of excavated rock from subsurface construction would remove or alter vegetation in the analyzed land withdrawal area and within the 37-square kilometer (9,100-acre) offsite area directly to the south. Approximately 2.5 square kilometers (620 acres) of the construction would occur in areas (both in the land withdrawal area and in the offsite area to the south) in which site characterization activities had already disturbed the vegetation; however, construction also would occur on as much as 6.5 square kilometers (1,600 acres) of undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area under the excavated rock pile.
Table 4-7 lists the amount of land that DOE would clear of vegetation for the majority of repository facilities by land cover type and compares this disturbance to the amounts of each land cover type in the

Table 4-7. Land cover types found in the region of influence (square kilometers).[a]

Land cover type	Area in Mojave and Nellis mapping zones in the State of Nevada[b]	Disturbed area under the Proposed Action[c]
Great Basin Pinyon-Juniper Woodland	4,000	0
Great Basin Xeric Mixed Sagebrush Shrubland	6,300	0.0023
Inter-Mountain Basins Big Sagebrush Shrubland	8,000	0
Inter-Mountain Basins Cliff and Canyon	410	0
Inter-Mountain Basins Greasewood Flat	1,400	0.0054
Inter-Mountain Basins Mixed Salt Desert Scrub	25,000	0
Inter-Mountain Basins Montane Sagebrush Steppe	20	0
Inter-Mountain Basins Semi-Desert Grassland	78	0
Inter-Mountain Basins Semi-Desert Shrub Steppe	4,500	0.15
Invasive Annual Grassland	55	0
Mojave Mid-Elevation Mixed Desert Scrub	3,600	1.7
North American Warm Desert Active and Stabilized Dune	2.9	0
North American Warm Desert Bedrock Cliff and Outcrop	350	0
North American Warm Desert Lower Montane Riparian Woodland and Shrubland	24	0
North American Warm Desert Playa	220	0.030
North American Warm Desert Volcanic Rockland	8.2	0
North American Warm Desert Wash	33	0
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	1,200	3.0
Sonora-Mojave Mixed Salt Desert Scrub	940	1.4
Totals[a]	57,000	6.3

Source: Derived from digital land cover map (DIRS 179926-USGS National Gap Analysis Program 2004, all) and land cover descriptions (DIRS 174324-NatureServe 2004, all) with the use of a geographic information system.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Numbers are rounded to two significant figures; therefore, totals might differ from sums.

b. Chapter 3, Section 3.1.5.1.1 contains a description of mapping zones.

c. Disturbed land cover area calculated only for disturbances for which a location has been identified. Total disturbance would be approximately 9 square kilometers.

Mojave and Nellis mapping zones in the State of Nevada. Removal of vegetation would result in impacts to small amounts of widely distributed land cover types that are common in the affected mapping zones (Chapter 3, Section 3.1.5.1.1 describes mapping zones), and these impacts would not cause a significant loss to any particular cover type. The largest losses would be to the Sonora-Mojave Creosotebush-White Bursage Desert Scrub land cover type, with disturbance of approximately 0.25 percent of the cover type in the Nellis and Mojave mapping zones in Nevada, land to the Sonora-Mojave Mixed Salt Desert Scrub land cover type, with disturbance of approximately 0.15 percent of the cover type in those mapping zones. Activities during repository construction, operation and monitoring, or closure would not reduce any other land cover type by more than 0.05 percent in the affected mapping zones.

Biological soil crusts likely occur within the region of influence in some areas where there has been no surface disturbance. Because insufficient data exist to assess the amount of biological crusts in the region of influence, and because attempts to locate or map occurrences of biological crusts could result in their disturbance or destruction, it would be extremely difficult for DOE to quantify the predicted impacts of repository construction or operations on biological crusts. However, any biological crusts in areas disturbed by repository construction or operations would be lost.

In cooperation with the U.S. Fish and Wildlife Service, DOE developed a site reclamation plan, in part to satisfy the terms and conditions of the 2001 Biological Opinion. DOE would reclaim lands it no longer needed for repository construction or operations and would monitor those lands to determine if reclamation efforts were successful. As stated in the *Reclamation Implementation Plan*, DOE considers reclamation successful if plant cover, density, and species richness are equal to, or exceed, 60 percent of the value of the same parameters in undisturbed reference areas (DIRS 154386-YMP 2001, pp. 33 and 34). If reclaimed sites meet these criteria, they can be released from further remediation and monitoring. As of April 2007, the Department had successfully reclaimed 119 sites [a total of 0.174 square kilometer (43 acres)] and released them from reclamation monitoring.

Repository construction activities that resulted in land disturbances and removal of vegetation could result in colonization by invasive plant species in additional areas. Invasive species that are currently present on the site (Chapter 3, Section 3.1.5.1.1) would be the most likely to colonize disturbed areas. Invasive species could suppress native species, although the reclamation actions described above could reduce the likelihood that they would overtake native species on reclaimed lands.

With an increase in invasive annual plants there could be an increase in fire fuel load from dried annual plants. Because the area that construction activities disturbed would be small in comparison with the total undisturbed vegetated area in the region of influence (Table 4-7), and because DOE would reclaim areas no longer in use as practicable, impacts to native species and the threat of increased fires would be small. Some invasive species would remain along permanent roads and drainage ditches where reclamation opportunities were limited, and these species could spread and overcome native species under certain conditions. Reclamation or other weed management strategies on long-term topsoil stockpiles and other disturbed areas would help control the abundance of invasive annuals such as red brome (*Bromus rubens*), and would minimize potential fire fuel load and disruption to native plant communities.

The Yucca Mountain FEIS cited studies that indicate that site characterization activities had very small effects on vegetation adjacent to DOE activities at Yucca Mountain. Therefore, impacts to vegetation from construction probably would occur only as a result of direct disturbance, such as during site clearing, and indirect disturbance, such as an increase in invasive annual plants as described above. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure.

Closure of the repository would involve the removal of structures and reclamation of areas that DOE cleared of vegetation for the construction of surface facilities as practicable and as delineated in the license amendment that DOE would have to obtain before closure. Final reclamation could include backfilling and grading to restore natural drainage patterns and create a stable landform; spreading and contouring topsoil that had been stockpiled during construction; creating erosion-control structures; ripping, seeding, spreading, and anchoring mulch; and fencing to reduce loss of new vegetation to herbivores. Figures 4-2, 4-3, and 4-4 illustrate the reclamation process the Department undertook during site characterization, which has improved the success rate of vegetation reestablishment and helps control encroachment of invasive species. These types of activities would be employed in the future to limit impacts of the Proposed Action.

Figure 4-2. Fill material is spread and contoured on the site of a decommissioned borrow area.

4.1.4.1.2 *Impacts to Wildlife*

This section summarizes, incorporates by reference, and updates the *Impacts to Wildlife* portion of Section 4.1.4.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-34 to 4-35). Direct impacts to wildlife would occur through four mechanisms: (1) loss of habitat from construction of facilities and infrastructure; (2) localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles, and deaths of individual animals from vehicle collisions; (3) fragmentation of undisturbed habitat that created a barrier to wildlife movement; and (4) displacement of wildlife because of an aversion to the noise and activity from construction, operation and monitoring, and closure of the repository.

Figure 4-3. Decommissioned borrow area that has been recontoured prior to seeding and mulching.

Figure 4-4. Decommissioned borrow area 4 years after reclamation.

DOE anticipates that the effect of these impacts on wildlife would be small because: (1) habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally; (2) animal species at the proposed repository site are generally widespread throughout the Mojave or Great Basin deserts, and the deaths of some individuals due to repository construction, habitat loss, and vehicle collisions would have small impacts on the regional populations of those species or on the overall biodiversity of the region; (3) large areas of undisturbed and unfragmented habitat would be available away from disturbed areas; and (4) impacts to wildlife from noise and vibration, if any, would be limited to the vicinity of the source of the noise (for example, heavy equipment, diesel generators, and ventilation fans). Overall, no species would be threatened with extinction, either locally, regionally, or globally. Several animals classified as game species by the State of Nevada [such as Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mule deer (*Odocoileus hemionus*)] are present in low numbers in the region of influence. Adverse impacts to these species would be unlikely and hunting opportunities would not change as DOE would continue to prohibit hunting in the area where most construction activities would occur. There would be no impact to desert bighorn sheep (*Ovis canadensis nelsoni*) in the offsite area to the south of the analyzed land withdrawal area, or their winter habitat in the Striped Hills, because the proposed addition to the access road to the Yucca Mountain site is more than a 1.6 kilometer (1 mile) west of the nearest potential habitat for sheep and there is no nearby suitable habitat to the west of the road. Construction and operations of other facilities or structures in the offsite area, such as new electric transmission lines, the Sample Management Facility, and a temporary construction camp, would have no impact on desert bighorn sheep because these actions would be far from important bighorn sheep habitat.

To avoid and minimize adverse impacts to migratory birds during repository construction, DOE would implement best management practices, which would include avoidance of groundbreaking activities to the maximum extent practicable in nesting habitat during the critical nesting period, which the Bureau of Land Management defines as May 1 through July 15. If groundbreaking or land clearing activities were necessary during the nesting season, DOE would conduct surveys for migratory bird nests before any such activities. The Department would prohibit all activities that would harm nesting migratory birds or result in nest abandonment.

Wildlife would be attracted to the water in lined evaporation ponds in the geologic repository operations area. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds depending on the depth and the slope of the sides. Previous experience has shown that a wide variety of animal species use such ponds and that DOE could avoid losses of animals by reduction of the pond slopes or by an earthen ramp at one corner of the pond. Appropriate engineering would minimize potential losses to wildlife.

As Chapter 3, Section 3.1.12.1 discusses, DOE could construct a landfill for construction debris and sanitary solid waste, although it has not determined a site for it. The landfill could attract scavengers such as coyotes (*Canis latrans*) and ravens (*Corvus corax*). Frequent covering of the sanitary waste in the landfill would minimize use by scavenger species.

After the completion of waste emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species could reoccupy the areas DOE reclaimed during the closure period.

4.1.4.1.3 *Impacts to Special-Status Species*

This section summarizes, incorporates by reference, and updates as indicated by new references the *Impacts to Special Status Species* portion of Section 4.1.4.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-35 to 4-36). The desert tortoise (*Gopherus agassizii*) is the only resident animal species in the analyzed land withdrawal area that is listed as threatened under the *Endangered Species Act* (16 U.S.C. 1531 et seq.). Further, there are no endangered or candidate animal species and no species that are proposed for listing (Chapter 3, Table 3-7). Repository construction would result in the loss of a small portion of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of tortoises is low.

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. DOE has successfully relocated two tortoise nests and 27 individual tortoises to protect them from potential threats. Since July 1997, three tortoises have been killed on access roads, none by construction activities (DIRS 182586-Spence 2007, all). Therefore, although some tortoises could be killed on roads during repository construction and as a result of increased vehicle traffic during repository operation, DOE anticipates the number of tortoise deaths due to vehicle traffic and construction activities during the repository construction, operations, monitoring, and closure periods would be small. However, the abundance of ravens, which are natural predators of juvenile desert tortoises, could increase as a result of infrastructure construction (the birds could use electric transmission lines and light posts as perches, for example) and could result in increased predation on young tortoises. Frequent covering of the sanitary waste in the potential landfill would limit the attraction of the repository area to ravens.

Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect the long-term survival of the local or regional population of this species. Yucca Mountain is surrounded to the east, south, and west by large tracts of undisturbed tortoise habitat on government property, and desert tortoises are widespread at low densities throughout this region.

The U.S. Fish and Wildlife Service has concluded that tortoise populations are depleted for more than 1 kilometer (0.6 mile) on either side of heavily used roads (DIRS 155970-DOE 2002, p. 4-36). The increase in traffic to Yucca Mountain would contribute to the continued depression of populations along U.S. Highway 95, but would not increase the threat to the long-term survival of tortoise populations in southern Nevada.

As required by Section 7 of the *Endangered Species Act*, DOE has entered into consultations with the U.S. Fish and Wildlife Service on the effects of proposed repository activities on the desert tortoise. The Fish and Wildlife Service issued a Biological Opinion in 2001, which concluded that “construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain is not likely to jeopardize the continued existence of the threatened Mojave population of the desert tortoise. These actions do not affect any area designated as critical habitat; therefore, no destruction or adverse modification of that habitat is anticipated” (DIRS 155970-DOE 2002, Appendix O, pp. 21 to 22). The Biological Opinion included reasonable and prudent measures, and terms and conditions required to achieve these measures, to ensure that implementation of the Proposed Action would not jeopardize the desert tortoise. Chapter 9, Section 9.2.4.1, of the Yucca Mountain FEIS lists these measures and describes how DOE is implementing them (DIRS 155970-DOE 2002, pp. 9-9 to 9-11). DOE would reinitiate consultation with the Fish and Wildlife Service if any of the conditions in 50 CFR 402.16 occurred, for example, if DOE exceeded the limit the Biological Opinion specified on the amount of tortoise habitat that DOE could disturb [6.65 square kilometers (1,643 acres)] (DIRS 155970-DOE 2002, Appendix O, p. 29).

The bald eagle (*Haliaeetus leucocephalus*) was observed once on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, eagles would be transient and repository activities would not affect them. The State of Nevada classifies the bald eagle as endangered.

Several animal species considered sensitive by the Bureau of Land Management (Chapter 3, Table 3-7) occur in the region of influence. Impacts to bat species would be small because of their low abundance on the site and broad distribution. Impacts to the common chuckwalla (*Sauromalus ater*) and Western burrowing owl *(Athene cunicularia hypugaea)* from disturbance or loss of individuals would be small because they are widespread regionally and are not abundant in the land withdrawal area. Impacts to the Western red-tailed skink (*Eumeces gilberti rubricaudatus*) would be small because it is widespread regionally and occupies small pockets of isolated habitat that would not be overly affected by any proposed disturbances. Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*) has been reported only in the southern portion of the land withdrawal area away from any proposed disturbances and, therefore, would not be affected.

Monitoring and closure activities at the repository would have little impact on desert tortoises or Bureau of Land Management sensitive species because the repository workforce would be smaller than during the operations period. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special-status species at the repository site could recolonize areas abandoned by humans.

4.1.4.1.4 *Impacts to Wetlands*

This section summarizes, incorporates by reference, and updates the *Impacts to Wetlands* portion of Section 4.1.4.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-36 to 4-37). There are no known naturally occurring wetlands subject to permitting requirements under Section 404 of the *Clean Water Act* (42 U.S.C. 1251 et seq.) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository activities would not affect the manmade well pond in the land withdrawal area. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of the facilities. After selecting the location of the facilities, DOE would conduct a formal delineation of waters of the United States near the surface facilities and, if necessary, develop a plan to avoid when practicable and otherwise minimize impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementation of the mitigation plan and compliance with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized. Appendix C contains a floodplain and wetlands assessment for the proposed repository.

4.1.4.2 Evaluation of Severity of Impacts to Biological Resources

Table 4-8 lists the results of the DOE evaluation of the impacts to biological resources.

4.1.4.3 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section summarizes and incorporates by reference Section 4.1.4.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 4-38 to 4-39); there have been no soil surveys that covered the region of

Table 4-8. Impacts to biological resources.

Analytical period	Flora	Fauna	Special-status species	Wetlands	Overall
Construction					
	Small; removal of vegetation from up to 9 square kilometers in widespread communities; maximum loss to any one land cover type in the affected mapping zones would be 0.25 percent	Small; loss of small amount of habitat and some individuals of some species	Small; loss of small amount of desert tortoise habitat and few tortoises	None	Small; loss of small amount of widespread but undisturbed habitat and small number of individuals
Operations					
	Small; disturbance of vegetation in areas adjacent to disturbed areas	Small; deaths of small number of individuals due to vehicle traffic and human activities	Small; potential deaths of few individuals due to vehicle traffic	None	Small; disturbance of common land cover types and loss of small number of individual animals
Monitoring					
	Small; no new disturbance of natural vegetation	Small; same as for operations, but smaller due to smaller workforce	Small; same as for operations, but smaller due to smaller workforce	None	Small; very small number of individual animals killed by vehicles
Closure					
	Small; decline in impacts due to reduction in human activity	Small; decline in number of individuals killed by traffic annually	Small; decline in number of individuals killed by traffic annually	None	Small; decline in impacts due to reduction of human activity
Overall rating of impacts	Small	Small	Small	None	Small

Note: Conversion factors are on the inside back cover of this Repository SEIS.

influence since completion of the FEIS. The evaluation of impacts to soils considered the potential for soil loss in disturbed areas, recovery of soil viability (that is, the physical, chemical, and biological properties of soil that foster plant growth) after disturbance, and the potential for the spread of contamination due to the relocation of contaminated soils (if present). DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the areas it had not reclaimed after the temporary disturbances following construction.

4.1.4.3.1 *Soil Loss*

Activities during the construction, operations, and monitoring periods would disturb varying amounts of land depending on the final design for the repository. DOE would disturb as much as 9 square kilometers

(2,200 acres) of land during the construction phase, which could expose bare soil to wind and water erosion.

During earlier activities, DOE established a reclamation program with a goal to return disturbed land to a condition similar to its predisturbance state (DIRS 154386-YMP 2001, all). One of the benefits of such a goal is the minimization of soil erosion. The program includes the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. Final reclamation would include spreading and contouring topsoil that was stockpiled during construction; creating erosion control structures; ripping, seeding, spreading, and anchoring mulch; and fencing to reduce loss of new vegetation to herbivores. The reestablishment of vegetation to stabilize stockpiled topsoil would reduce the construction loss of the most critical type of soil.

DOE would use fugitive dust control measures, which would include water spraying, chemical treatment, and wind fences as appropriate, to minimize wind erosion of the stockpiled topsoil and excavated rock. The Department would minimize soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as control of storm water runoff through the use of holding ponds, baffles, and other devices, and the stabilization of disturbed ground, relocated soil, or excavated material. Based on past experience and the continuing topsoil protection and erosion control programs, DOE anticipates little soil loss due to erosion during any phase of the project.

4.1.4.3.2 *Recovery*

Studies during the Yucca Mountain site characterization effort and experience at the Nevada Test Site indicate that natural succession on disturbed dry, semiarid lands would be a very slow process. Soil recovery would be unlikely without reclamation. DOE remains fully committed to the reclamation of disturbed areas (DIRS 154386-YMP 2001, Section 1.2).

Land disturbances can compromise or destroy soil viability through salvaging, stockpiling, and compaction. Topsoil handling and stockpiling can have negative impacts on the physical, chemical, and biological properties of the soil, which include decreased soil stability and porosity, increased bulk density, increased ammonium concentrations, decreased nutrients and microbial populations, decreased viable seed populations, and decreased organic matter. While DOE could not avoid most of these impacts, the use of proper techniques for soil handling, stockpiling, and stabilization would minimize them. DOE studied stockpiling and stabilization during site characterization and identified methods that had little effect on chemical and physical proprieties, nutrient content, or microbial content of the soil (DIRS 150174-CRWMS M&O 1999, all). DOE used the study results and information from literature searches to develop a topsoil management plan (DIRS 154386-YMP 2001, Section 4.2). Use of the techniques in this plan would result in minimum impacts on soil viability from salvaging and stockpiling activities.

4.1.4.3.3 *Contamination*

There would be a potential for spills or releases of contaminants under the Proposed Action (Section 4.1.3.1.2), but DOE would implement an updated version of its *Spill Prevention, Control, and Countermeasures Plan for Site Activities* (DIRS 172055-DOE 2004, all) to prevent, control, and remediate soil contamination. The Department would train workers in the handling, storage, distribution, and use of hazardous materials to provide practical prevention and control of potential contamination sources. Fueling operations and storage of hazardous materials and other chemicals would take place in bermed areas and away from floodplains when possible to decrease the probability of unexpected water flow spreading an inadvertent spill. DOE would provide rapid-response cleanup and response capability, techniques, procedures, and training for potential spills.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section summarizes, incorporates by reference, and updates the information in Section 4.1.5 of the Yucca Mountain FEIS (DIRS 155790-DOE 2002, pp. 4-39 to 4-41). In this Repository SEIS, the region of influence for cultural resources includes the analyzed land withdrawal area, land that DOE has proposed for an access road from U.S. Highway 95, and land where DOE would construct offsite facilities.

Cultural resources are nonrenewable resources with values that physical disturbance could diminish. The Yucca Mountain FEIS evaluation of impacts to cultural resources considered the potential for disruption or modification of the character of cultural resources. The evaluation placed particular emphasis on identification of the potential for impacts to archaeological and historic sites and other cultural resources important to sustaining and preserving American Indian cultures.

For this Repository SEIS, direct comparison of disturbed land as the predominant indicator enables determination of impacts to cultural resources. The primary sources of short-term impacts from construction, operation and monitoring, and closure would be facility construction and operations and human activities.

Overall, estimated impacts to cultural resources identified in this Repository SEIS would be small, as described below.

4.1.5.1 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

The following sections discuss archaeological and historic resources in the region of influence and the American Indian viewpoint on DOE activities related to the proposed repository and their impacts on these resources.

4.1.5.1.1 *Archaeological and Historic Resources*

The Yucca Mountain FEIS identified direct and indirect impacts to archaeological and historic resources. Direct impacts would be those from ground disturbances or activities that destroyed or modified the integrity of archaeological or historic sites, and indirect impacts result from activities that could increase the potential for intentional or unintentional adverse impacts (for example, increased human activity near resources could result in illicit collection or inadvertent destruction). The FEIS concluded that although there could be some indirect impacts, the overall effect of the proposed repository on the long-term preservation of archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Limited access to and use of the area would protect archaeological and historic resources in most of the area from most human intrusion.

The Yucca Mountain FEIS recommended that 51 of the 830 archaeological and historic sites were eligible for inclusion in the *National Register of Historic Places*. In consultation with the Nevada State Historic Preservation Office, DOE has revised its recommendation to include 232 sites (DIRS 182189-Rhode 2007). The revised number reflects recent investigations for the U.S. Highway 95 access road and a reevaluation of the importance of obsidian artifacts. Recent studies suggest that obsidian artifacts can provide important information on prehistoric American Indian settlement systems. The large increase in the number of eligible archaeological sites since completion of the FEIS reflects this finding and includes extractive (for example, toolstone quarrying, hunting, and seed gathering) and processing (for example, animal butchering, milling plants, or cooking) localities where obsidian toolstone is present.

Potential impacts to *National Register*-eligible archaeological sites could occur from land disturbances due to construction. An evaluation by the Desert Research Institute identified 57 archaeological sites and 75 isolated artifacts (DIRS 182189-Rhode 2007) in the construction areas. Three of these 57 sites have been recommended for inclusion in the *National Register*. The *National Register*-eligible sites consist of two prehistoric temporary camps and one resource processing locality. Before construction began, DOE would avoid or mitigate impacts to archaeological and historic resources, so direct adverse impacts from construction and operation of the facilities would be small.

Improved access to the area could lead to indirect impacts from unauthorized excavation or collection of artifacts. DOE would mitigate these impacts through personnel training, archaeological and historic site monitoring, and long-term management. These measures would protect archaeological and historic resources from most human intrusions in the analyzed land withdrawal area. This added protection would result in a beneficial effect.

A draft programmatic agreement among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Officer has been prepared for cultural resources management related to activities that would be associated with development of a repository at Yucca Mountain. While this agreement is in ongoing negotiation among the concurring parties, DOE is abiding by the process set forth in Section 106 of the *National Historic Preservation Act of 1966* (16 U.S.C. 470).

4.1.5.1.2 *American Indian Viewpoint*

In the Yucca Mountain FEIS, DOE summarized the American Indian view of resource management and preservation, which is holistic in its definition of cultural resources and incorporates all elements of the natural and physical environment in an interrelated context. In the FEIS, DOE committed to continue the Native American Interaction Program throughout implementation of the Proposed Action to enhance the protection of archaeological sites and cultural items important to American Indians. The FEIS reported that construction activities would have no direct impacts on several delineated American Indian sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. However, because of the general level of importance that American Indians attribute to these places, which they believe are parts of an equally important integrated cultural landscape, American Indians consider the intrusive nature of the proposed repository to be a significant adverse impact to all elements of the natural and physical environment. Based on Tribal Update Meetings for members of the Consolidated Group of Tribes and Organizations held since the completion of the FEIS, the American Indian viewpoint is unchanged.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from construction and operation of the proposed Yucca Mountain repository. The analysis for the Yucca Mountain FEIS examined the potential for socioeconomic impacts in Clark, Lincoln, and Nye counties in southern Nevada. For this Repository SEIS, the region of influence consists of Clark and Nye counties (Chapter 3, Section 3.1.7).

Evaluations of the socioeconomic environment—in Nye County where the repository would be and in Clark County where most workers would live—considered changes to employment, population, three economic measures (real personal disposable income, spending by state and local government, and Gross Regional Product), housing, and some public services. The evaluation used the Regional Economic Models, Inc. (REMI) model, *Policy Insight*, version 9, to estimate and project baseline socioeconomic conditions from 2005 to 2067 for employment and population changes that would be due to the Proposed Action. DOE developed baselines for Gross Regional Product, real disposable personal income, and spending by state and local governments for Clark and Nye counties and for the State of Nevada (DIRS 178610-Bland 2007, all). Chapter 3, Section 3.1.7 presents baseline information that describes the current socioeconomic environment in the region of influence. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region of influence where most of the repository workers would live. Although the analysis focused on *regional* impacts, DOE acknowledges that Clark County, which has 50 times as many people as Nye County, dominates the region and often obscures impacts in Nye County. DOE has noted when the impact in Nye County would differ meaningfully from regional impacts.

DOE examined the employment that would be necessary for construction and operation of a repository. The Yucca Mountain FEIS analysis projected baseline population and employment in the region of influence to 2035. For this Repository SEIS analysis, DOE included anticipated incremental changes above and below the employment and population projections to 2067 that could result from the Proposed Action. In addition, this section provides estimates and projections through 2067 of baseline values for several economic parameters and estimates of incremental changes attributable to the construction and operation of the proposed repository above and below the baselines for Clark and Nye counties and the State of Nevada.

Socioeconomic impacts described in this Repository SEIS would vary from impacts DOE identified in the Yucca Mountain FEIS because of different underlying assumptions. For the FEIS, the data for analysis of the potential impacts to socioeconomic variables, all of which would be driven by changes in the number of jobs, were based on the employment levels of construction and operations workers assigned to the proposed repository site. That analysis did not include other project jobs, engineering and project safety for example, because those jobs would be off the site, primarily in the Las Vegas area.

The analysis for this Repository SEIS included present and projected offsite workers as well as onsite workers. In addition, estimated worker requirements in this document are specific to the modified repository design and operational plans, while the Yucca Mountain FEIS considered several operating modes and, to bound the evaluation, based potential impacts on the mode that would require the greatest number of workers. The analysis used updated baselines for the evaluated socioeconomic variables. As a result of the refined data, potential impacts to Gross Regional Product, real disposable personal income, spending by state and local governments, housing, and public services from changes in employment and population would be smaller than the impacts the FEIS reported.

4.1.6.1 Socioeconomic Impacts from Construction and Operations

4.1.6.1.1 *Impacts to Employment*

Surface and subsurface construction would begin in 2012. DOE would scale back surface construction in 2016 as emplacement began (in 2017). Subsurface construction would begin in 2012, escalate in 2018, moderate at approximately 170 employees by 2026, and continue until 2042. The number of employees for subsurface construction would be considerably fewer than the number of workers for surface construction. In 2014, the peak year of direct employment during the initial construction period, DOE would employ about 2,590 workers (which would represent about 1,090 newly created jobs) for the Proposed Action. About 1,860 of these workers would be employed on the site and 730 workers would work off the site, primarily in the Las Vegas area. Construction workers would include skilled craft workers and professional and technical support personnel (engineering, safety analysis, safety and health, and other field personnel). Onsite employment during construction would peak in 2016 with about 1,920 workers as DOE transferred offsite positions and responsibilities from Clark County sites to the repository in Nye County.

EMPLOYMENT TERMS

Direct Employment: Jobs that are expressly associated with project activity.

Indirect Employment: Jobs that are created as a result of expenditures by directly employed project workers (for example, restaurant workers or childcare providers) or jobs that are created by project-related purchases of goods and services (for example, sales manager of a concrete supply store).

Composite Employment: Sum of direct and indirect employment.

Figure 4-5 shows composite (direct and indirect) employment changes due to construction activities under the Proposed Action by county of residence. Incremental employment increases during the construction period would peak in 2014 with the addition of about 1,000 jobs in the region of influence (about 690 in Clark County and 310 in Nye County). The number of additional jobs in the region of influence would be virtually identical to the number of additional jobs in the State of Nevada because the direct jobs would be confined to Clark and Nye counties, where DOE assumed all workers would reside, and thus new indirect jobs would probably be in the same jurisdictions. The change in the number of new jobs would be less than the number of onsite jobs because some of those would be filled by construction workers who had completed another assignment and some would be filled by individuals who joined the construction industry from another field and were, therefore, part of the baseline employment estimates. Not all project-related jobs would require that individuals move into the region of influence. Employment in the construction industry is constantly in flux, and assignments begin and end in a relatively short period so some repository jobs would be filled by workers already in the region. The number of onsite jobs would increase as the number of offsite professional and technical positions decreased.

The dynamics of the economies in each county and the number of directly employed workers who lived in each county would influence the numbers and locations of indirect jobs. The Proposed Action would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 1,329,000 jobs to slightly less than 1,330,000 positions—a regional change of approximately 0.08 percent, but 1.5 percent in Nye County. These changes would be small. REMI uses historical patterns of spending and in-migration to predict changes. Table 4-9 summarizes peak construction year changes in direct employment by county of worker residence.

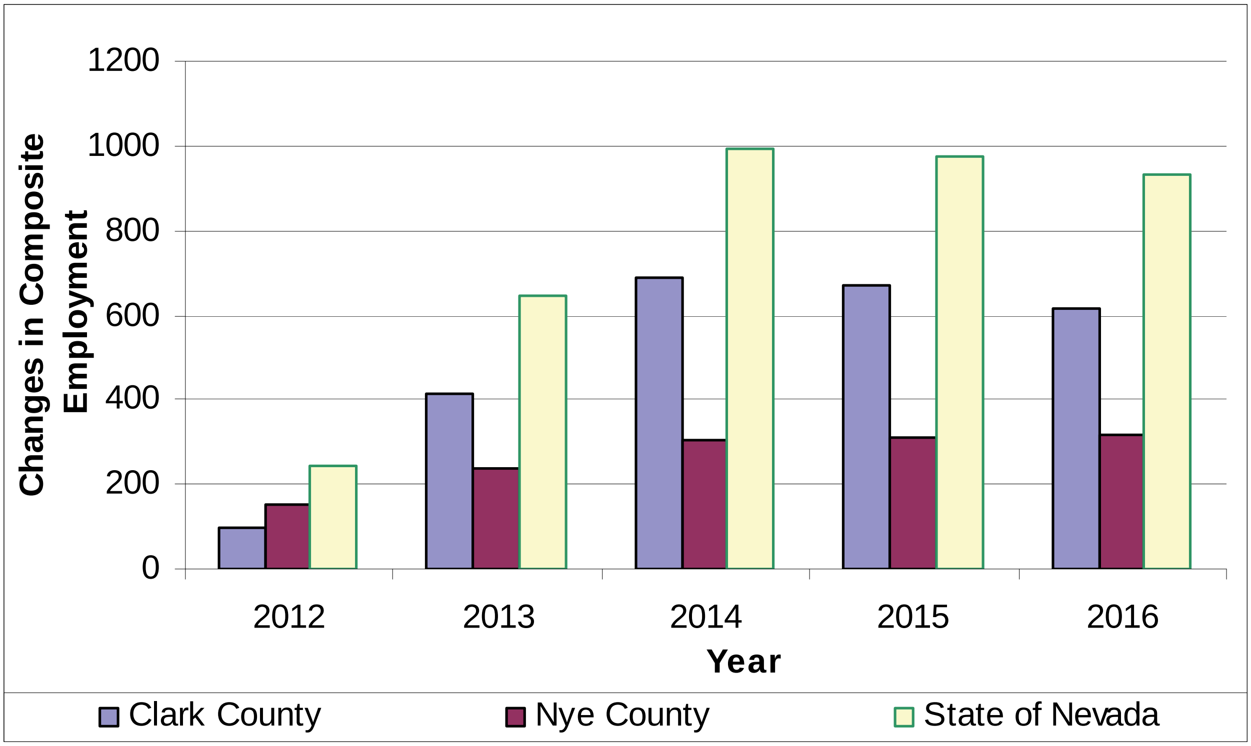


Figure 4-5. Increases in composite regional and State of Nevada employment during construction.

Table 4-9. Expected peak construction year (2014) changes in direct employment by county of worker residence.

Area	Employees[a]
Clark County	758
Nye County	328
Region of Influence	1,090

Source: DIRS 182205-Bland 2007, all.
Note: Numbers have been rounded to three significant figures.
a. Excludes 216 current onsite workers and 1,286 offsite workers.

Table 4-10 lists the expected distribution of project job locations during the initial construction period. Chapter 3, Section 3.1.7 discusses residential distribution patterns of Yucca Mountain Project workers.

Table 4-10. Repository direct employment during initial construction period by county of job location.[a]

Area	2012	2013	2014	2015	2016
Clark County (offsite)	709	711	730	648	589
Nye County (onsite)	1,010	1,480	1,860	1,900	1,920
Total project employment	1,720	2,200	2,590	2,550	2,510

Source: DIRS 182205-Bland 2007, all.
Note: Numbers have been rounded to three significant figures; therefore, totals might differ from sums.
a. Includes current positions.

Emplacement would begin in 2017. Although subsurface construction would continue until about 2042, this Repository SEIS refers to the period from 2017 to 2067 as the operations period. Emplacement activities could continue for up to 50 years from the beginning of emplacement in 2017 until 2067.

Direct operations peak employment would occur in 2019 when repository operations would require about 2,690 workers. About 2,070 of these workers would be on the site, and the remaining 620 would work in the Las Vegas area. Project-related direct employment would range from 2,600 to 2,300 from 2017 to 2024, then range from 2,300 to 2,000 until 2040. Employment levels from 2041 to 2067 would be essentially stable at about 700 workers (DIRS 182205-Bland 2007, all).

Table 4-11 lists the expected distribution of changes in regional employment in the peak year of employment (2021) during the operations period. The table lists the estimated number of repository-induced jobs in Clark and Nye counties and in Nevada in 2021. Employment in the region of influence would peak with approximately 1,300 workers. The employment baselines in Clark and Nye counties have grown rapidly since completion of the Yucca Mountain FEIS. New indirect jobs result from new direct jobs unless there is some capacity of existing business to meet the increased demand for goods and services. The region, especially Clark County, probably has sufficient excess capacity and impacts would be spread over a number of communities in Clark County, such that the number of indirect jobs would be lower. This would result in a small incremental increase of regional employment from the estimated baseline of about 1,425,000 jobs to about 1,426,000 jobs, a change of less than 0.1 percent from the estimated employment baseline for 2021.

Table 4-11. Expected peak year (2021) increases in operations period composite employment in the region and in the State of Nevada.

Area	Employees	% change
Clark County	861	0.06
Nye County	437	2.0
Total increase in jobs in region of influence	1,300	0.09
State of Nevada	1,300	0.07

Source: DIRS 182642 -Bland 2007, all.
Note: Numbers have been rounded to three significant figures; therefore, totals might differ from sums.

Table 4-12 summarizes direct repository employment from 2017 to 2067 by expected county of job location. Figure 4-6 shows changes in regional employment for Clark and Nye counties and for the State of Nevada. Beginning in 2042, the rate of employment growth in the region would slow as the need for repository workers dropped. The growth would slow by about 148 jobs in 2042, to about 312 jobs in 2045, and would continue slowing by about 230 jobs through 2067. Given the expected economic growth in the region of influence, the region could readily absorb declines in repository employment as subsurface construction and emplacement activities ended. The Yucca Mountain Project would continue to contribute positively to the economy, but losses of offsite jobs would result in the slower growth of jobs in the region. Impacts to regional employment, employment in Clark County and Nevada from repository-related construction and operations would be small, less than 1 percent. Impacts in Nye County would be greater, but not more than 2 percent of the baseline.

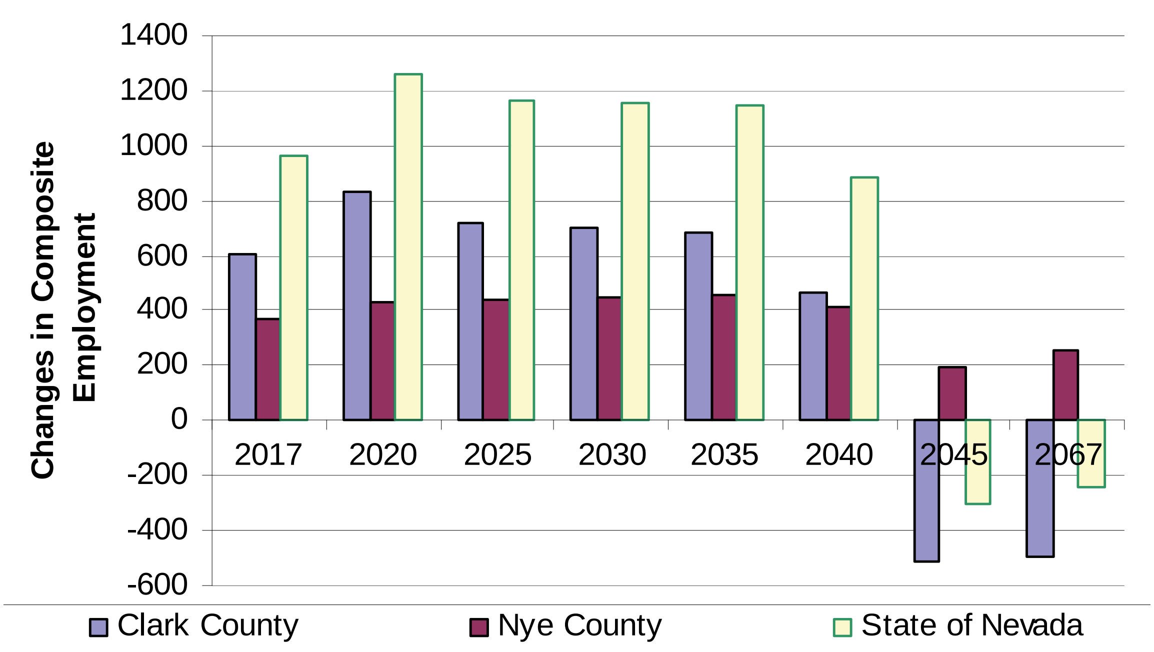
4.1.6.1.2 *Impacts to Population*

DOE based assumptions about future residential distribution on worker preferences consistent with historical preferences (Chapter 3, Section 3.1.7). Historical patterns of behavior, including choice of preferred county of residence, might not be an accurate barometer of future trends because of the uncertainties in prediction of human behavior. The analysis based estimates of impacts to socioeconomic

Table 4-12. Repository direct employment[a] during the operations period by county of job location, 2017 to 2067.

Area	2017	2020	2025	2030	2045	2067
Clark County (offsite)	572	585	470	470	144	108
Nye County (onsite)	1,940	2,000	1,820	1,800	562	421
State of Nevada	2,510	2,590	2,290	2,270	706	529

Source: DIRS 182205-Bland 2007, all.
Note: Numbers have been rounded to three significant figures.
a. Includes current positions.



DIRS 182642-Bland 2007, all

Figure 4-6. Changes in composite regional employment from repository operations activities in the region and in Nevada.

variables in the region on the assumption that 80 percent of the workers at the site would live in Clark County and 20 percent would live in Nye County. Those persons working in Clark County are assumed to live in Clark County.

The analysis projected that regional population would grow from about 2,480,000 residents in 2012 to approximately 5,130,000 in 2067 (DIRS 178610-Bland 2007, all). The peak year population contribution in the region of influence attributable to the repository, 2035, would be approximately 2,280 people, or about 0.06 percent of the estimated population baseline of 3,630,000 people (DIRS 178610-Bland 2007, all). In general, increases in population occur several years after increases in employment because some workers delay relocation. Clark County would experience the peak increase in population in 2034 and Nye County would experience a peak in 2039. This phenomenon would largely be due to the fact that Clark County has such a large labor pool, and most project workers and family members would already live there and would not in-migrate to the county. Because the labor force is smaller in Nye County, many project workers or workers who filled the new indirect jobs and who lived in Nye County would represent a new household in the county. The increase in population would represent a small increase, about 1.2 percent of the county's baseline population in 2039. The Proposed Action would have only small effects on population growth in the region of influence. Figure 4-7 shows the projected population increases from the repository project for Clark and Nye counties and the State of Nevada. Prediction of specific residential preferences for one community over another in a county is inexact, so the estimated and projected residential distribution patterns are at the county and state levels rather than the community level.

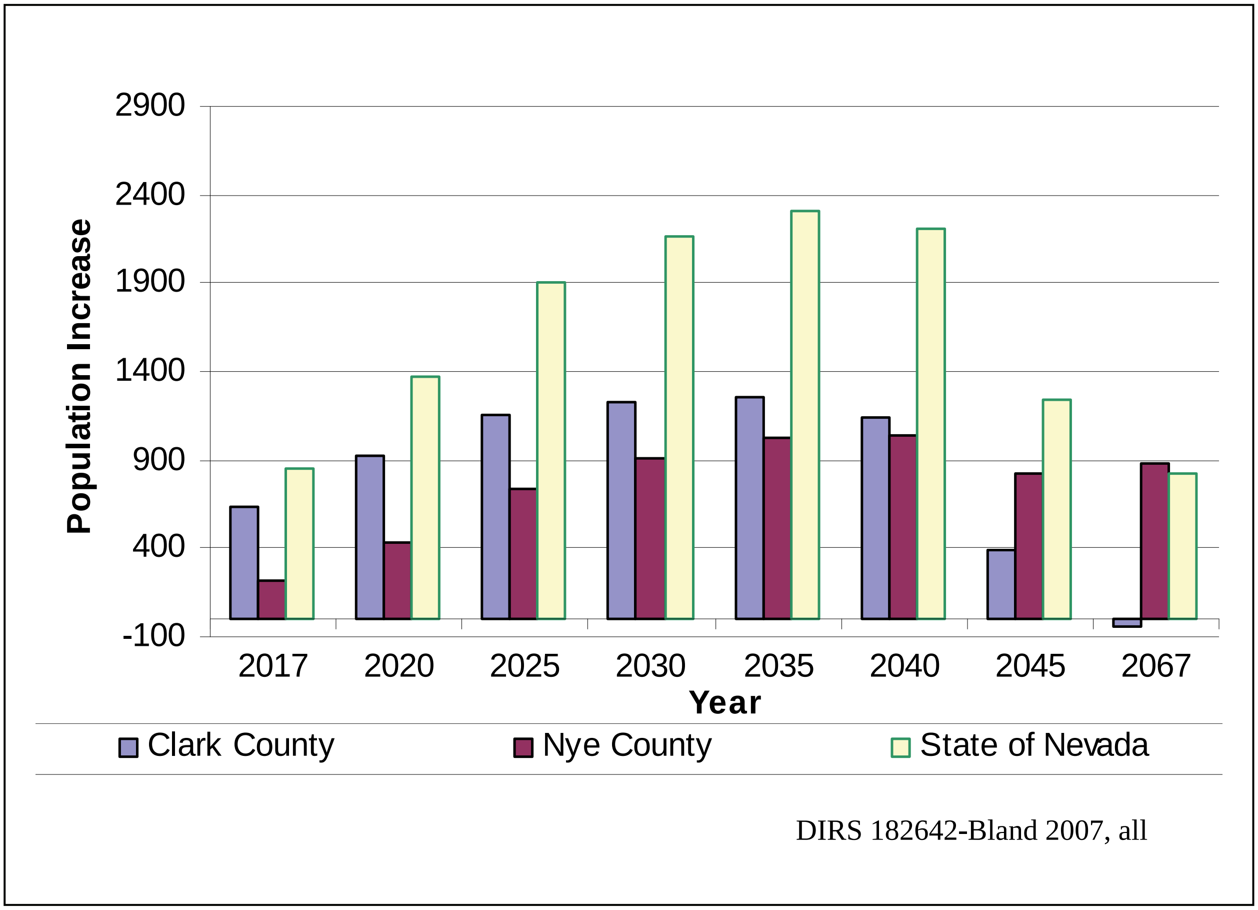


Figure 4-7. Regional population increases from operations, 2017 to 2067.

Table 4-13 lists estimated incremental population increases that would result from repository activities. The incremental peak population increase in Clark County would be about 0.04 percent. Population growth from repository activities would be more evident in Nye County. The county's population increase would be approximately 1.2 percent of the projected population of 84,000 (DIRS 178610-Bland 2007, all) for the county in 2035, which would be the peak period for potential repository population impacts.

Table 4-13. Estimated population increase in Clark County, Nye County, and the State of Nevada from Proposed Action (2035).

Area	Total population[a]
Clark County	1,260
Nye County	1,020
State of Nevada[b]	2,310

Source: DIRS 182642 -Bland 2007, all.
a. Numbers have been rounded to three significant figures.
b. Includes population outside of the region of influence.

The estimated changes in population from repository activities would be small in Clark and Nye counties. The workers' choices of place of residence would have a large influence on population increases above the projected baselines. To present a more complete profile of potential impacts, DOE examined a second residential distribution and analyzed potential impacts to socioeconomic variables from that scenario. The alternative distribution includes an analysis of changes in employment, population, three economic measures, and demand for housing and some public services. Appendix A, Section A.4 contains the results of that analysis.

4.1.6.1.3 *Impacts to Economic Measures*

Table 4-14 lists estimated changes in economic measures that would result from repository activities during the construction period (values are in 2006 dollars). Repository-induced impacts as measured by these economic variables would essentially be confined to the region of influence and, therefore, would be the same for the State of Nevada. Increases in real disposable personal income in the region of influence would peak in 2014 with an increase of about $57.8 million, $41.7 million, or 0.05 percent in Clark County and $16.0 million, or 1.1 percent in Nye County. Increases in Gross Regional Product would also peak in 2014 at about $80.5 million. About $58.9 million or 0.05 percent of the change in Gross Regional Project would happen in Clark County. The impact in Nye County would be 1.4 percent above the baseline or $21.6 million. Regional expenditures by the State of Nevada and local governments would peak at $3 million in 2016. Clark County expenditures would account for $2.3 million of the change in

GROSS REGIONAL PRODUCT

The value of all final goods and services produced in the region of influence.

Table 4-14. Increases in economic measures in Clark County, Nye County, and the State of Nevada from repository construction, 2012 to 2016 (millions of 2006 dollars).

Area	2012	2013	2014	2015	2016
Clark County					
State and local government spending	0.2	0.6	1.2	1.8	2.3
Real disposable personal income	4.2	23.9	41.7	40.5	38.4
Gross Regional Product	6.2	33.3	58.9	58.3	54.9
Nye County					
State and local government spending	0.1	0.2	0.4	0.5	0.7
Real disposable personal income	7.6	12.2	16	16.6	17.1
Gross Regional Product	10	16.1	21.6	20.8	22.7
State of Nevada					
State and local government spending	0.3	0.8	1.7	2.4	3
Real disposable personal income	12	36.5	58.3	57.8	56.1
Gross Regional Product	16.2	49.3	80.3	79.1	77.6

Source: DIRS 182642 -Bland 2007, all.

spending. The change in both counties would be less than 0.03 percent. Economic measures for the region of influence would increase by less than one-tenth of 1 percent over the projected baseline (estimated economic measures without the repository project).

Table 4-15 lists the changes in economic measures, for representative years, that would result from the repository project during the operations period. Increases in Gross Regional Product would peak in 2034 at about $98.7 million, or 0.05 percent in Clark County and $68.9 million, or a small 2.7 percent above the baseline in Nye County for a total of $168 million. Increases in regional real disposable personal income would also peak in 2034 at $85.7 million. Clark County would experience a 0.05-percent increase $58.3 million and Nye County would experience about $27.4 million, or a 1.3-percent increase.

Table 4-15. Changes in economic measures in Clark County, Nye County, and the State of Nevada from emplacement activities, 2017 to 2067 (millions of 2006 dollars).

Area	2017	2020	2025	2030	2035	2045	2067
Clark County							
State and local government spending	3.0	4.0	5.0	5.0	5.7	2.0	0.0
Real disposable personal income	40.0	57.0	53.0	55.0	56.2	-34.0	-38.0
Gross Regional Product	58.0	89.0	87.0	92.0	95.0	-92.0	-105.0
Nye County							
State and local government spending	1.0	2.0	3.0	4.0	5.0	4.0	4.0
Real disposable personal income	18.0	21.0	23.0	25.0	27.5	16.0	23.0
Gross Regional Product	34.0	47.0	57.0	63.0	68.8	31.0	42.0
State of Nevada							
State and local government spending	4.0	6.0	8.0	10.0	10.9	6.0	4.0
Real disposable personal income	59.0	79.0	77.0	81.0	84.9	-16.0	-15.0
Gross Regional Product	91.0	136.0	144.0	155.0	164.3	-60.0	-64.0

Source: DIRS 182642 -Bland 2007, all.

Increases in regional expenditures by state and local government would peak in 2035 at about $10.7 million. Most of the incremental spending would occur in Clark County, about $5.7 million, which would be a small increase of 0.04 percent. Spending in Nye County would be about $5 million or 1.3 percent of the baseline. The impacts in Nye County would be proportionately greater because the repository would be in Nye County. Economic activity, which would include incidental spending by workers who lived in Clark County but worked in Nye County, would be responsible for this phenomenon. In addition, Nye County would experience many indirect jobs with consequent income and taxes. Economic measures for the region of influence would increase by less than 0.1 percent over the projected baseline. Impacts in the State of Nevada and the region of influence would be essentially the same because changes from economic baselines would be driven largely by changes in employment and population, and those changes would occur almost exclusively in Clark and Nye counties.

4.1.6.1.4 *Impacts to Housing*

Given the size of the projected regional employment, the number of workers who would in-migrate to work on the repository would be relatively small. Because the in-migration would be small, the increased demand for housing would be small. Because the maximum change above the population baselines would be so small in Clark County (about 1,260 persons) and in Nye County (about 1,050 persons), demands on the regional housing inventory should be similarly small. In general, housing stock increases at approximately the same ratio as the population. Impacts to housing would be minimal because (1) the expected increase in regional population would be small, (2) the demand would primarily be in metropolitan Clark County, (3) there are no municipal or state growth control measures that limit housing development, and (4) the region of influence has an adequate supply of undeveloped land to meet expected future demands.

Impacts to housing would be more pronounced in Nye County, particularly in Pahrump. Because Nye County and Pahrump have recently experienced rapid and largely unanticipated growth, the county has a limited housing inventory to absorb new workers and worker families. Much of the infrastructure to support housing development is at capacity.

During the late 1990s and early 21st century, the Bureau of Land Management sold approximately 13,500 acres of public land within a specific boundary around Las Vegas. Much of the land was sold to the private sector, and particularly to developers of large master-planned communities. These additional lands have helped to accommodate population growth in the greater Las Vegas area. Nye County has also acquired land to facilitate and accommodate the orderly development of land uses that repository activities could trigger.

DOE analyzed potential impacts to housing at the county level. The Department did not attempt to predict incremental housing demand at the community level because housing preferences (mobile home, modular assembly, stick-built), density or cluster choices (single family, multifamily), and desired lot sizes are difficult to predict. Because the incremental increase in population from repository-related activities would occur over a long period and be more predictable, the private sector housing market could readily adapt. In addition, given the very large housing inventory in the region, the region's baseline growth would mask the changes that were due to the repository.

4.1.6.1.5 *Impacts to Public Services*

Repository-generated impacts to public services such as schools, public safety, and medical services in the region of influence from population changes attributable to construction and operation of the repository would be small. Population changes from repository-related employment would be a small fraction of the anticipated population growth in the region. Even without the addition of repository jobs, the annual regional growth rate would increase by an estimated 1.4 percent through 2050, which would minimize the need to alter plans already in place to accommodate projected growth. As mentioned above, the majority of in-migrating workers would probably live in the many communities of metropolitan Clark County, thereby dispersing the increased demand for public services.

Southern Nye County, particularly Pahrump, would experience an increased demand for public services. However, because the anticipated increases over the baseline population in the county would be small and would occur incrementally over a long period, the county might be able to absorb increased demands in education, law enforcement, and fire protection (public safety) as the local government expanded the levels of these services to accommodate the anticipated non-repository related growth. The county and communities in the county would continue to provide services as the revenue base grew. Although these public services are currently at capacity, it is uncertain what the infrastructure capacity would be as repository operation began or in 2039 when the repository-related population increase reached its peak with about 1,050 residents or a small increase of 1.2 percent above the baseline. Repository-related population increases in Nye County would be less than 1.3 percent during the entire construction and operations periods. DOE facilities have historically had cooperative agreements with local governments for mutual aid and support of emergency services. If DOE implemented such an agreement in conjunction with the Proposed Action, strains on regional emergency services infrastructure would be reduced. Repository-generated impacts to public services such as education and public safety could require mitigation because the current structure for the generation of local government revenues, primarily from property taxes, would not support the expanded level of services that additional residents would require. The recently opened hospital in Pahrump and the ample services in the metropolitan Las Vegas area could serve to alleviate the scarcity of medical services in Nye County.

4.1.6.2 Summary of Socioeconomic Impacts

For all five socioeconomic parameters that DOE evaluated over the construction and operations periods, the regional impacts would be small, less than 1 percent of the baselines. The operations period would result in higher impacts to employment, population, Gross Regional Product, real disposable personal income, and state and local government spending. Changes in regional employment, which would include direct and indirect workers, would peak in 2021. The increase of about 1,300 workers would represent a 0.09-percent increase above the projected baseline for that year. Gross Regional Product would peak in 2034 because of consumption of goods and services due to construction activities. The estimated increase in Gross Regional Product for 2034 would be about $168 million in 2006 dollars or 0.08 percent of the baseline. Population increases from increased employment opportunities would peak in 2035 at about 2,280 or 0.06 percent of the baseline for the year. Government spending would also peak in 2035 at an increase of $10.7 million or 0.07 percent of the baseline. Real disposable personal income would be highest during the operations period and would peak in 2034 at $85.7 million or 0.07 percent more than the baseline. The regional impacts as measured by all five parameters would be small in all years, as they would be in Clark County. The impacts would be greater, but still small, in Nye County. As a percentage, the greatest population impact would be 1.2 percent in 2034 or 2035, and employment impacts would reach 2.0 percent in 2021. Spending by local government would peak at 1.3 percent in 2019, and real disposal personal income would increase by 1.4 percent in 2019. The Nye County Gross Regional Product would increase by 2.8 percent in 2023.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes potential health and safety impacts to workers (occupational impacts) and to members of the public (public impacts) from construction, operation and monitoring, and eventual closure of the proposed repository. Members of the public would be outside the land withdrawal area. The analysis estimated occupational health and safety impacts separately for involved and noninvolved workers for each repository analytical period—construction, operations, monitoring, and closure. Involved workers would be craft and operations personnel who were directly involved in facility construction and operations activities, which would include excavation; receipt, handling, packaging, aging, and emplacement of spent nuclear fuel and high-level radioactive waste; monitoring of the conditions and performance of the waste packages; and closure. Noninvolved workers would be managerial, technical, supervisory, and administrative personnel who would not be directly involved in those activities.

This section summarizes, incorporates by reference, and updates as necessary Section 4.1.7 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-48 to 4-63). Potential health and safety impacts to repository workers would include those from industrial hazards common to the workplace, from exposure to naturally occurring and manmade radiation and radioactive materials in the workplace, and from exposure to naturally occurring nonradioactive airborne hazardous materials. Members of the public could be exposed to airborne releases of naturally occurring and manmade radionuclides and naturally occurring hazardous materials. The analysis based estimates of public health impacts from nonradioactive sources on the air quality information in Section 4.1.2.

CONCEPT OF INVOLVED AND NONINVOLVED WORKERS

Nonradiological Impacts
Involved workers would be those doing the physical work of constructing, operating, monitoring, and closing the repository.

Noninvolved workers would be managerial, technical, supervisory, and administrative personnel onsite.

There would be no nonradiological impacts to DOE workers at the Nevada Test Site.

Radiological Impacts
Involved workers would be those directly engaged in developing subsurface facilities during the construction and operations periods and spent nuclear fuel and high level waste processing, emplacement and maintenance during operating, monitoring, and closing the repository.

Noninvolved workers would be managerial, technical, supervisory, and administrative personnel onsite and workers engaged in surface construction during the construction period and the first several years of repository operations, when surface and subsurface construction and operations would proceed in parallel.

DOE workers at the Nevada Test Site were treated separately as noninvolved worker population.

4.1.7.1 Nonradiological Impacts

4.1.7.1.1 *Impacts to Occupational and Public Health and Safety During Construction*

This section describes estimates of nonradiological health and safety impacts to repository workers and members of the public for the 5-year construction period. Activities would include site preparation, infrastructure construction, construction of surface facilities, and initial construction of subsurface facilities. Potential health and safety impacts to workers could occur from industrial hazards, exposure to naturally occurring cristobalite and erionite in the rock at Yucca Mountain, and unexploded ordnance. Potential health impacts to members of the public could occur from exposure to airborne releases of naturally occurring hazardous materials (cristobalite and erionite) and from criteria pollutants.

Occupational Health and Safety Impacts
Industrial Hazards. The Repository SEIS analysis estimated health and safety impacts to workers from industrial hazards using the same method as the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 4-50). The CAIRS database provided industrial accident statistics from DOE experience with activities similar to those proposed for repository construction (DIRS 182198-DOE 2007, all; DIRS 182199-NNSA 2007, all). DOE uses CAIRS to collect and analyze reports of injuries, illnesses, and other accidents that occur during its operations. Information from the database included two impact categories—total recordable cases; and Days Away, Restricted, or On Job Transfer cases. The latter category is equivalent to the U.S. Department of Labor Bureau of Labor Statistics lost workday cases category.

INDUSTRIAL HAZARDS TERMINOLOGY

Total Recordable Cases
The total number of work-related deaths, illnesses, or injuries that resulted in the loss of consciousness, restriction of work or motion, transfer to another job, or required medical treatment beyond first aid (DIRS 182204-DOE 2004, all).

Lost Workday Case
A case that involves days away from work or days of restricted work activity, or both. Equivalent to Days Away, Restricted, or On Job Transfer case in the CAIRS database (DIRS 182204-DOE 2004, all).

Fatality
Any death that results from workplace activities.

Full-Time Equivalent Worker Years
The number of employees who would be involved in an activity calculated from work hours. Each full-time equivalent worker year consists of 2,000 work hours (the number of hours DOE assumed for one worker in a normal work year).

CAIRS provides total recordable cases and lost workday cases incidence rates per 100 full-time equivalent worker years and provides fatality statistics used to calculate fatality incidence rates per 100,000 worker years. Table 4-16 lists the incident rates for involved construction workers and noninvolved workers at DOE facilities from the past 5 years. To estimate impacts to workers from industrial hazards, DOE multiplied those rates by the number of full-time worker years during the construction period for the proposed repository and divided the results by 100. The statistics for noninvolved workers are from the Government and Service Operation categories. The CAIRS database contains no involved construction worker and 1 noninvolved worker fatality at DOE facilities during the past 5 years. The fatality rate for noninvolved workers was calculated as 0.55 per 100,000 full-time equivalent worker years. To be conservative, the analysis used the fatality rate of 0.55 per 100,000 full-time equivalent worker years to estimate worker fatalities from industrial hazards for both involved and noninvolved workers. For comparison, there have been no reported fatalities as a result of workplace

Table 4-16. Health and safety statistics for estimation of occupational safety impacts for involved and noninvolved construction workers.[a]

Worker type	Rate of total recordable cases per 100 FTEs	Rate of lost workday cases per 100 FTEs[b]
Involved worker	2.0	0.86
Noninvolved worker	1.5	0.69

Note: Numbers are rounded to two significant figures.
a. Construction worker statistics from 2002 to 2006 from CAIRS (DIRS 182199-NNSA 2007, all).
b. Equivalent to Days Away, Restricted, or On Job Transfer in CAIRS.
FTE = Full-time equivalent worker year.

activities for the Yucca Mountain Project. Table 4-17 lists the estimated numbers of full-time equivalent worker years during the construction period for involved and noninvolved workers. Table 4-18 lists the estimated impacts to workers for the construction period from industrial hazards.

Table 4-17. Estimated full-time equivalent worker years during construction period.

Worker group	Number
Involved workers[a]	
Surface construction	5,500
Subsurface construction	340
Involved workers total	5,800
Noninvolved workers[a]	
Noninvolved workers total	2,200

Source: DIRS 182205-Bland 2007, all.
Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.
a. Workers at site; does not include employees in Las Vegas offices.

Table 4-18. Impacts to workers from industrial hazards during construction period.

Worker group and impact category	Number
Involved workers	
Total recordable cases	120
Lost workday cases[a]	50
Fatalities	0.032
Noninvolved workers	
Total recordable cases	34
Lost workday cases[a]	15
Fatalities	0.012
All workers (totals)	
Total recordable cases	150
Lost workday cases[a]	66
Fatalities	0.044

Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.
a. Equivalent to Days Away, Restricted, or On Job Transfer in CAIRS.

Naturally Occurring Hazardous Materials. Workers at the Yucca Mountain site could encounter two types of naturally occurring hazardous materials—cristobalite, a form of crystalline silica (silica dioxide), and erionite, a naturally occurring zeolite. Both have the potential to become airborne during repository excavation and tunneling operations, or the excavated rock pile could release them as dust. Cristobalite is in the welded tuff at the repository level and makes up between 18 and 28 percent of the tuff mineral content (DIRS 104523-CRWMS M&O 1999, p. 4-81). Erionite is an uncommon zeolite mineral that forms wool-like fibrous masses and occurs in rock layers below the proposed repository level. Based on geologic studies to characterize the repository horizon, most repository operations should not disturb erionite because it appears to be absent or rare at the repository level (Chapter 3, Section 3.1.8.3). Erionite could become a hazard during vertical boring operations if the operations passed through an erionite-bearing rock layer (which would be unlikely). Appendix F, Section F.1.2 of the Yucca Mountain FEIS contains more detail on the potential hazards of these minerals (DIRS 155970-DOE 2002, pp. F-12 to F-14).

DOE would use engineering controls (as part of best management practices) during subsurface work to control exposures of workers to silica dust. These controls would include the use of dust shields and air curtains on tunnel boring machines, water sprays and atomizing nozzles, isolated work areas, air stream scrubbing, and provision of fresh air to work areas through duct lines. In addition, DOE would design and operate the ventilation system to control ambient air velocities to minimize dust resuspension. The Department would monitor the work environment to ensure that dust concentrations did not exceed the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, DOE would use administrative controls such as access restrictions or respiratory protection until the engineering controls could establish acceptable conditions. The Department would apply similar controls, if necessary, for surface workers. DOE anticipates that exposure of workers to silica dust would be below the applicable limits and that potential impacts to subsurface and surface workers would be small.

The engineering controls for exposure to silica dust would apply to potential exposure to erionite. DOE does not expect to encounter erionite layers at the proposed repository depth and location. If there was an erionite encounter, DOE would seal off the area and evaluate remediation methods to eliminate worker exposure throughout the repository tunnels.

Unexploded Ordnance. There have been U.S. Air Force and other military training activities in the region in the past. Portions of the construction area could have unexploded ordnance in surface locations. Unexploded ordnance could include shell casings, projectiles, or fragments, as well as live small arms ammunition, bombs, and rockets. DOE would coordinate with the Air Force about construction activities and would follow standard and established procedures for unexploded ordnance. An unexploded ordnance specialist would develop a plan, including evaluation of potential types of unexploded ordnance possible, depths, and other factors. Unexploded ordnance technicians would screen areas where there was a potential for unexploded ordnance before construction crews began work.

Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.1 presents estimated annual maximum concentrations of cristobalite at the boundary of the analyzed land withdrawal area where exposures to members of the public could occur during the construction period. There are no regulatory limits for public exposure to cristobalite. An EPA health assessment (DIRS 103243-EPA 1996, p. 1-5) stated that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 micrograms per cubic meter multiplied by the number of years of exposure. The analysis established a benchmark annual average concentration of 10 micrograms per cubic meter over a 70-year lifetime. The estimated cristobalite concentrations at the boundary of the land withdrawal area would be about 0.048 microgram per cubic meter. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower. Health impacts would be unlikely.

Criteria Pollutants. Section 4.1.2.1 presents estimated maximum concentrations of criteria pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter) at the boundary of the analyzed land withdrawal area where exposures to members of the public could occur during the construction period. (As Section 4.1.2 describes, the maximum air concentration from repository activities could occur at different locations along the boundary of the land withdrawal area dependent on the release period and the averaging time of a particular criteria pollutant. The maximally exposed individual would be the person at the location with the highest concentration per release period and averaging time.) The analysis estimated that concentrations would be less than 1 percent of the regulatory limits for all criteria pollutants except particulate matter. $PM_{2.5}$ could have a maximum concentration of about 1 percent of the 24-hour regulatory limit, and PM_{10} could have a maximum concentration of about 60 percent of the 24-hour regulatory limit. Although DOE would use dust suppression measures to reduce the PM_{10} concentration, the impact analysis did not consider such measures. Health impacts to the public would be small.

4.1.7.1.2 *Impacts to Occupational and Public Health and Safety During Operations*

This section describes potential health and safety impacts to workers and members of the public during the operations period. For analytical purposes, this period would begin with receipt of a license amendment to receive and possess spent nuclear fuel and high-level radioactive waste and would include waste receipt, handling, aging, emplacement, and monitoring. Subsurface development and surface facility construction would continue during the period. The operations period would last up to 50 years and would end with emplacement of the last waste package. Potential health and safety impacts to workers could occur from industrial hazards and exposure to naturally occurring cristobalite and erionite in the rock at Yucca Mountain. Potential health impacts to members of the public could occur from exposure to airborne releases of naturally occurring hazardous materials and from criteria pollutants.

Occupational Health and Safety Impacts

Industrial Hazards. The analysis used the method DOE established in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-54 and 4-55) to estimate health and safety impacts to workers from industrial hazards. Table 4-19 lists the estimated number of full-time equivalent worker years during the operations period.

Table 4-19. Estimated onsite full-time equivalent worker years during operations period.

Worker group	Number
Involved workers[a]	
Surface construction	2,700
Subsurface construction	4,300
Emplacement Operations	12,000
Emplacement Operations: Maintenance	4,900
Involved worker total	23,000
Noninvolved workers[a]	
Noninvolved workers total	36,000

Source: DIRS 182205-Bland 2007, all.
Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.
a. Workers at site; does not include employees in Las Vegas offices.

The incident rates for involved construction workers (which would include subsurface development workers) and noninvolved workers during the operations period would be identical to the incident rates for the construction period (Table 4-16). Table 4-20 lists the incident rates for involved workers who were engaged in operation activities during the remainder of the operations period. The rates are statistics from similar activities at DOE facilities (Savannah River Site, Idaho National Laboratory, and Oak Ridge National Laboratory) for 2002 through 2006. No fatalities were recorded at the three DOE facilities during the 5-year reporting period. Therefore, to be conservative, DOE used the fatality rate of 0.55 per 100,000 full-time equivalent worker years that was used for repository construction. Table 4-21 lists the estimated industrial hazards impacts to workers for the operations period.

Table 4-20. Health and safety statistics for estimation of occupational safety impacts common to the workplace for operations period involved workers.[a]

Rate of total recordable cases per 100 FTEs	Rate of lost workday cases per 100 FTEs[b]
1.4	0.58

Note: Numbers are rounded to two significant figures.

a. Statistics from 2002 to 2006 for activities at Savannah River Site, Idaho National Laboratory, and Oak Ridge National Laboratory from CAIRS (DIRS 182198-DOE 2007, all).

b. Equivalent to Days Away, Restricted, or On Job Transfer in CAIRS.

FTE = Full-time equivalent worker year.

Table 4-21. Impacts to workers from industrial hazards during operations.

Worker group and impact category	Number
Involved workers	
Surface construction	
Total recordable cases	53
Lost workday cases[a]	23
Fatalities[b]	0.015
Subsurface construction	
Total recordable cases	87
Lost workday cases[a]	37
Fatalities[b]	0.024
Emplacement operations	
Total recordable cases	160
Lost workday cases[a]	67
Fatalities[b]	0.064
Emplacement operations: maintenance	
Total recordable cases	68
Lost workday cases[a]	28
Fatalities[b]	0.027
Noninvolved workers	
Total recordable cases	540
Lost workday cases[a]	250
Fatalities[b]	0.20
All workers (totals)	
Total recordable cases	910
Lost workday cases[a]	400
Fatalities[b]	0.33

Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.

a. Equivalent to Days Away, Restricted, or On Job Transfer in CAIRS.

b. Fatality impacts based on fatality rate from Table 4-16.

Naturally Occurring Hazardous Materials. As Section 4.1.7.1.1 discusses for the construction period, cristobalite and erionite have the potential to become airborne during continuing repository excavation and as fugitive dust from the excavated rock pile. DOE would use engineering controls and, if necessary, administrative measures to control and minimize impacts to workers from releases of cristobalite and erionite during the operations period. Impacts would be small.

Public Heath Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.2 presents estimated annual maximum concentrations of cristobalite at the boundary of the analyzed land withdrawal area where exposures to members of the public could occur during the operations period. The analysis estimated concentrations of cristobalite of about 0.002 microgram per cubic meter. This would be about 0.02 percent of the benchmark concentration of 10 micrograms per cubic meter. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure.

Criteria Pollutants. Section 4.1.2.2 presents estimated maximum concentrations of criteria pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter) at the boundary of the land withdrawal area where exposures to members of the public could occur during the operations period. The analysis estimated that concentrations would be less than 2 percent of the regulatory limit for all criteria pollutants except particulate matter. $PM_{2.5}$ would have a maximum concentration of less than 3 percent of the 24-hour regulatory limit, and PM_{10} would have a maximum concentration of less than 9 percent of the 24-hour regulatory limit. Health impacts to the public would be unlikely.

4.1.7.1.3 *Impacts to Occupational and Public Health and Safety during Monitoring*

This section describes estimated health and safety impacts to workers and members of the public during the monitoring period. For analytical purposes, this period would begin with the emplacement of the final waste package and would continue for 50 years. Activities during this period would include ventilation maintenance; remote inspection of waste packages; retrieval, if necessary, of waste packages to correct detected problems; and investigations to support predictions of postclosure repository performance. Potential health and safety impacts to workers could occur from industrial hazards and exposure to naturally occurring cristobalite and erionite in the rock at Yucca Mountain. Potential health impacts to members of the public could occur from exposure to airborne releases of naturally occurring hazardous materials and from criteria pollutants.

Occupational Health and Safety Impacts

Industrial Hazards. The analysis conservatively assumed that health and safety impacts for the monitoring period would be similar to those in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Table 4-27, p. 4-57) even though the duration of the period in the FEIS was 26 years longer. The total recordable cases for all workers could be 380. The estimated lost workday cases for all workers would be 160, and the estimated fatalities for all workers would be 0.36.

Naturally Occurring Hazardous Materials. Monitoring activities would be unlikely to generate large quantities of dust for extended periods. For the monitoring period, DOE would use engineering controls and administrative worker protection measures such as respiratory protection as necessary to control and minimize impacts to workers from releases of cristobalite and erionite during monitoring activities (Section 4.1.7.1.1).

Public Heath Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3 presents air emissions impacts during the monitoring period. After completion of emplacement, DOE would continue monitoring and maintenance activities. Subsurface excavation would be complete, so there would be less emissions of naturally occurring hazardous materials in comparison to previous periods. Cristobalite concentrations at the analyzed land withdrawal area boundary would be substantially lower than those during the construction and operations periods. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than during previous periods.

Criteria Pollutants. During the monitoring period, criteria pollutant emissions would decrease in comparison to previous periods because construction, excavation, and emplacement activities would be complete. Pollutant concentrations at the land withdrawal area boundary would be substantially lower than those for the construction and operations periods. Health impacts to the public would be unlikely.

4.1.7.1.4 *Impacts to Occupational and Public Health and Safety during Closure*

This section describes estimated health and safety impacts to workers and members of the public during the closure period. For analytical purposes, this period would begin with receipt of a license amendment to close the repository, would last 10 years, and would overlap the last 10 years of the monitoring period. Activities during this period would include closure of subsurface repository facilities, backfilling, sealing of openings to the underground, removal of surface facilities, erection of monuments, and reclamation of disturbed lands. Health and safety impacts to workers could occur from industrial hazards and exposure to naturally occurring cristobalite and erionite in the rock at Yucca Mountain. Health impacts to members of the public could occur from exposure to airborne releases of naturally occurring hazardous materials and from criteria pollutants.

Occupational Health and Safety Impacts

Industrial Hazards. The analysis assumed that health and safety impacts for the closure period would be similar to those in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Table 4-30, p. 4-59). The estimated total recordable cases for all workers would be 370. The estimated lost workday cases for all workers would be 180. The estimated fatalities for all workers would be 0.2.

Naturally Occurring Hazardous Materials. Closure activities could generate dust (for example, during preparation and emplacement of excavated rock for backfill). The potential for dust generation, especially in the underground environment, would be less than that for subsurface excavation during the construction and operations periods. As necessary, DOE would use the engineering controls and worker protection measures (Section 4.1.7.1.1) it developed for the construction period to control and minimize potential impacts to workers. Potential impacts would be small.

Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.4 presents estimated annual maximum concentrations of cristobalite at the boundary of the analyzed land withdrawal area where there could be exposures to members of the public during the closure period. The analysis estimated concentrations of about 0.0026 microgram per cubic meter. This would be less than 0.03 percent of the benchmark concentration of 10 micrograms per cubic meter. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure.

Criteria Pollutants. Section 4.1.2.4 presents estimated maximum concentrations of criteria pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter) at the boundary of the land withdrawal area where there could be exposures to members of the public during the closure period. The estimated concentrations would be less than 0.06 percent of the regulatory limit for all criteria pollutants except particulate matter. $PM_{2.5}$ could have a maximum concentration of about 0.5 percent of the 24-hour regulatory limit, and PM_{10} could have a maximum concentration of about 19 percent of the 24-hour regulatory limit. Health impacts to the public would be unlikely.

4.1.7.1.5 *Total Impacts to Occupational and Public Health and Safety for All Periods*

This section presents estimates of the total impacts to workers from industrial hazards from activities at the proposed repository. For this analysis, the entire project duration would be 105 years and would consist of a 5-year construction period, a 50-year operations period, a 50-year monitoring period, and a 10-year closure period that would overlap the last 10 years of the monitoring period. As noted above, health impacts to the public from naturally occurring hazardous material and criteria pollutants would be unlikely. Therefore, DOE did not quantify total health impacts to members of the public.

Table 4-22 lists total impacts to workers from industrial hazards for the entire project.

Table 4-22. Total impacts to workers from industrial hazards for all periods.

Worker group and impact category	Number
Involved workers	
Total recordable cases	1,100
Lost workday cases[a]	490
Fatalities	0.62
Noninvolved workers	
Total recordable cases	680
Lost workday cases[a]	310
Fatalities	0.30
All workers (totals)	
Total recordable cases	1,800
Lost workday cases[a]	800
Fatalities	0.92

Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.

a. Equivalent to Days Away, Restricted, or On job Transfer in CAIRS.

4.1.7.2 Radiological Impacts

This section describes potential radiological health and safety impacts to workers and members of the public from construction, operation, monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved and noninvolved workers for each repository period. The types of potential health and safety impacts to workers would include those from exposure to naturally occurring and manmade radiation and radioactive materials in the workplace. The estimated radiological impacts include potential doses and radiological health impacts for the maximally exposed involved workers and the involved worker populations; radiological health impacts for the maximally exposed noninvolved workers and the noninvolved worker populations; and the estimated collective dose and radiological health impacts for the combined worker population. Radiological health impacts for maximally exposed individuals are the estimated increase in the probability of a latent cancer fatality that would result from the received radiation dose. Radiological health impacts for affected populations are the number of latent cancer fatalities DOE estimates would result from the collective radiation doses.

There would be exposure of members of the public to airborne releases of naturally occurring and manmade radionuclides from repository activities. The analysis estimated radiation doses and health impacts for the maximally exposed offsite individual and the potentially exposed population. The maximally exposed offsite individual would be a hypothetical member of the public at a point on the analyzed land withdrawal boundary who would receive the highest radiation dose and resultant radiological health impact. This location would be at the southeast boundary of the analyzed land withdrawal area. The exposed population would be that within 80 kilometers (50 miles) of the repository.

Appendix D describes the methodology, data, and calculation of estimated radiological health and safety impacts to workers and members of the public and includes detailed results. Chapter 5 discusses the potential human health impacts of postclosure repository performance.

CONSERVATIVE ASSUMPTIONS USED IN RADIOLOGICAL IMPACT ANALYSIS

Radiological Impacts to Workers:
The maximally exposed involved worker would be a worker whose entire working lifetime would span the total operations period up to 50 years for handling of spent nuclear fuel.

The involved worker population would be exposed to conservatively estimated dose rates emitted from the casks based on the design-basis commercial spent nuclear fuel characteristics used for shielding design. This conservative approach would result in overestimate of the impacts to workers by a factor of about 3 if dose rates were based on the average spent fuel nuclear fuel characteristics that DOE would process at the proposed repository.

DOE applied no administrative limits to reduce individual exposures for its conservative estimates of involved worker doses.

Impacts to Members of the Public:
The location of the maximally exposed member of the public would be an hypothetical individual who would reside continuously for 70 years at the unrestricted public access area in the prevailing downwind direction from the repository that would receive the highest radiation exposure.

4.1.7.2.1 *Changes since the Publication of the Yucca Mountain FEIS*

The following paragraphs summarize the primary changes from the Yucca Mountain FEIS analysis to that for this Repository SEIS.

Population Distribution Data
The duration of the operations period would be 50 years and would begin in 2017. Because this Repository SEIS assesses radiological impacts to the population within 80 kilometers (50 miles) of the repository, the analysis updated the population projection to 2067 based on projected changes in the region, including the towns of Beatty, Pahrump, Indian Springs, and the surrounding rural areas (Chapter 3, Section 3.1.8).

Spent Nuclear Fuel Characteristics
To estimate the magnitude of the radioactive releases under normal operations, the Repository SEIS analysis conservatively assumed that all spent nuclear fuel at the repository would consist of the same composition of radionuclides. The fuel characteristics for the analysis were those of a pressurized-water reactor design-basis fuel assembly, which has the characteristics of 4-percent initial enrichment with a

burnup level of 60,000 megawatt-days per metric ton of heavy metal and a cooling (aging) time of 10 years after removal from a reactor (DIRS 161120-BSC 2002, Section 5.5).

Dose Assessment Computer Program

The analysis used CAP88-PC (Version 3) (DIRS 179923-Shroff 2006, all), an atmospheric transport model for assessment of dose and risk from radioactive air emissions, to calculate collective dose to the public and the dose to the maximally exposed individual. CAP88-PC is EPA-approved for the demonstration of compliance with the National Emission Standards for Hazardous Air Pollutants standards [40 CFR 61.93(a)]. EPA validated the program through comparison of predictions of annual average concentrations to actual environmental measurements at five DOE sites (DIRS 179923-Shroff 2006, Section 1.4). The program provides capabilities for radon release dispersion and exposure calculations that include receptor radon progeny concentrations in working levels. It incorporates updated dose factors that follow the Federal Guidance Report 13 method (DIRS 175452-EPA 1999, all). The Federal Guidance Report 13 factors are based on the methods in Publication 72 of the International Commission on Radiological Protection (DIRS 172935-ICRP 2001, all).

Meteorological Data

Meteorological input data to CAP88-PC used the joint frequency distribution of wind speed, direction, and atmospheric stability class based on onsite meteorological measurements from 2001 to 2005 (DIRS 177510-BSC 2007, all and Attachment III).

Updated Latent Cancer Fatality Conversion Factors

For this Repository SEIS analysis, DOE updated the latent cancer fatality conversion factor to 0.0006 latent cancer fatality per person-rem for conversion of worker and public doses to health effects. This conversion factor is from current DOE guidance (DIRS 178579-DOE 2004, pp. 22 to 24; DIRS 174559-Lawrence 2002, p. 2 and Appendix D).

4.1.7.2.2 *Radiological Health Impacts During Construction*

Activities during the 5-year construction period would include site preparation and construction of infrastructure that included the Initial Handling Facility, the balance of plant facilities that would support initial receipt of waste, a Canister Receipt and Closure Facility, an aging facility, the Wet Handling Facility, and initial construction of subsurface facilities for emplacement. DOE would construct the Initial Handling Facility and the balance of plant facilities first; the Canister Receipt and Closure Facility, aging facility, and Wet Handling Facility would proceed in parallel.

Radiological health and safety impacts to workers could occur from exposure to naturally occurring radionuclides in the rock and from exposure to airborne releases of naturally occurring radionuclides (radon-222 and its decay products). Column 2 of Table 4-23 (in Section 4.1.7.2.6) lists estimates of radiological impacts to workers for the construction period.

Health Impacts to Workers

There would be no spent nuclear fuel and high-level radioactive waste at the repository site during the construction period, so they would not contribute to radiological impacts. Radiological health impacts to involved and noninvolved workers in subsurface facilities during the construction period would be from two sources: internal exposure from inhalation of radon-222 and its decay products that emanated from the host rock, and external exposure from naturally occurring radionuclides in the drift walls. Measurements in the Exploratory Studies Facility indicated an underground ambient external dose rate from radionuclides in the drift walls of about 50 millirem per worker year of 2,000 hours underground (DIRS 155970-DOE 2002, p. 3-99).

During the construction period the only source of radiation would be from naturally occurring radionuclides in the subsurface, so subsurface facility construction workers would incur most of the radiological health impacts to the workforce. The estimated increase in the number of latent cancer fatalities for workers would be about 0.02 and the estimated increase in probability of a latent cancer fatality for the maximally exposed worker would be about 0.0003.

Public Health Impacts

Potential radiological health impacts to the public during the 5-year construction period would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. Column 2 of Table 4-24 (in Section 4.1.7.2.6) lists estimates of radiological impacts to the public for the construction period. The estimated number of latent cancer fatalities in the public from repository construction would be about 0.05 in a projected population of about 117,000 persons within 80 kilometers (50 miles) of the repository. The estimated increase in probability of a latent cancer fatality for the maximally exposed member of the public would be about 0.000002 over the 5-year period.

The increase in radiological impacts to the public population since DOE completed the Yucca Mountain FEIS is primarily a result of the reduced stack height of the subsurface ventilation exhausts from 60 meters (200 feet) to close to ground level. DOE adopted this design change to improve safety in relation to potential external events such as an airplane crash, earthquake, and high winds. The primary parameters that contribute to the increase are (1) a factor of about 5 from reduced stack height from 60 meters to about ground level, (2) a factor of about 2 from varied change of site meteorological parameter height data (for wind speed and frequency toward the population centers) from 60-meter height to ground level, and (3) a factor of 1.5 from increased population projection within 80 kilometers (50 miles) of the repository.

4.1.7.2.3 *Estimated Radiological Health Impacts During Operations*

The operations period would begin with the receipt of an NRC license to receive and possess radiological materials and would include receipt, handling, aging, and emplacement of waste. During the operations period, surface facility construction would continue and include a Receipt Facility and additional Canister Receipt and Closure Facilities. DOE would add aging facilities as needed. The operations period would last up to 50 years and would end with emplacement of the last waste package. Subsurface construction (development) would continue into the operations period for approximately 22 years.

Health Impacts to Workers

Occupational radiological health impacts during the operations period would be a combination of impacts to surface workers during spent nuclear fuel and high-level radioactive waste handling operations and impacts to subsurface workers during development and emplacement operations. The principal contributors to radiological health impacts during the operations period would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for aging and emplacement. Column 3 of Table 4-23 (in Section 4.1.7.2.6) lists the estimated radiological impacts to workers for the operations period.

The estimated number of latent cancer fatalities in the worker population for up to a 50-year operations period would be 3.6 latent cancer fatalities (Table 4-23 in Section 4.1.7.2.6). The estimated increase in probability of a latent cancer fatality for the maximally exposed individual would be 0.018.

Public Health Impacts

Potential radiological health impacts to the public from operations period activities would result from (1) exposure to naturally occurring radon-222 and its decay products in subsurface exhaust ventilation air and (2) exposure to potential releases to the air of gases and particulates from damaged spent nuclear fuel during handling operations in the Wet Handling Facility. The manmade radionuclides from the spent nuclear fuel would contribute small radiological impacts—about 0.1 percent of the dose—in comparison to that from radon-222 and its decay products. Column 2 of Table 4-24 (in Section 4.1.7.2.6) lists estimates of radiological impacts to the public for repository operations.

For the operations period, the estimated increase in probability of a latent cancer fatality in the maximally exposed member of the public would be about 0.0002. The estimated number of latent cancer fatalities in the affected population would be about 4.

4.1.7.2.4 *Estimated Radiological Health Impacts During Monitoring*

The monitoring period would begin with emplacement of the last waste package and continue for 50 years. The first 3 years of this period would include decontamination of surface handling facilities. The last 10 years would overlap with the closure period. Columns 4 of Tables 4-23 and 4-24 (in Section 4.1.7.2.6) list the estimates of radiological impacts to workers and the public, respectively, for monitoring the repository.

Health Impacts to Workers

Occupational radiological health impacts during monitoring would be a combination of impacts to surface workers during facility decontamination and subsurface workers during monitoring and maintenance activities. The principal contributor to radiological health impacts would be from subsurface facility monitoring and maintenance activities.

The estimated number of latent cancer fatalities in the worker population for the first 40 years of the monitoring period would be about 0.6. The estimated radiological health impacts to the maximally exposed individual would be 13 rem, which would represent an increase in probability of latent cancer fatality of 0.008.

Public Health Impacts

Potential radiological health impacts to the public from monitoring activities would result from exposure to releases of naturally occurring radon-222 and its decay products in subsurface exhaust ventilation air. DOE does not anticipate that decontamination activities would generate releases of radioactive material to the environment or radiation doses to the public.

Table 4-24 in Section 4.1.7.2.6 lists the estimates of dose and potential radiological health impacts to the public for the first 40-years of the monitoring period. The increase in probability of a latent cancer fatality in the maximally exposed member of the public would be 0.00016, and the number of latent cancer fatalities that could occur in the affected population would be 3.7.

4.1.7.2.5 *Estimated Radiological Health Impacts During Closure*

The closure period would begin at the completion of the first 40 years of monitoring and last 10 years.

Health Impacts to Workers
During the closure period, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from naturally occurring radionuclides in the drift walls, and to external radiation from the waste packages. Most of the radiation dose and potential radiological health impacts for this period would be to subsurface workers, and the maximally exposed worker would be a subsurface worker. There would be low potential for exposure of surface workers. Column 5 of Table 4-23 (in Section 4.1.7.2.6) lists the estimated radiological impacts to workers for the closure period. The estimated number of latent cancer fatalities in the worker population for the 10-year closure period would be 0.25. The estimated radiological health impacts to the maximally exposed worker would be 1.6 rem with an increase in probability of latent cancer fatality of 0.001.

Public Health Impacts
Potential radiological health impacts to the public from closure activities would result from exposure to releases of radon-222 and its decay products in the subsurface exhaust ventilation air. The estimated dose and radiological health impacts for this period would be small. Table 4-24, column 5 (in Section 4.1.7.2.6) lists estimates of radiological impacts to the public for the closure period. The increase in probability of a latent cancer fatality in the maximally exposed member of the public for the closure period of 10 years would be 0.00002. The estimated number of latent cancer fatalities in the affected population would be about 0.5.

4.1.7.2.6 *Estimated Radiological Health Impacts for Entire Project Period*

This section summarizes the radiological human health and safety impacts to workers and members of the public from activities at the proposed repository. The project duration would be 105 years and would include 5 years of construction, 50 years of operations, 50 years of monitoring, and 10 years of closure, which would overlap the final 10 years of the monitoring period. In general, the highest potential health and safety impacts would occur during the operations and monitoring periods.

Radiological Health Impacts to Workers for Entire Project
Table 4-23 (last column) lists total radiation dose and radiological health impacts to workers for the entire project. Doses and impacts for the maximally exposed worker are for the operations period. The collective dose to the worker population and potential radiological health impacts are for the entire project duration of 105 years.

The maximally exposed worker would be a *surface facility worker* whose entire working lifetime would span the total operations period for handling of spent nuclear fuel. This worker would be a cask operator who handled spent nuclear fuel. The estimated radiation dose would be 30 rem if DOE did not apply administrative limits to reduce individual exposures. The increase in probability of a latent cancer fatality would be about 0.02 for this individual.

The estimated total worker population radiation dose for the entire project duration of 105 years would be 7,400 person-rem. About 80 percent of the dose would occur during the operations period for the repository workforce. The principal source of exposure would be external radiation from handling of spent nuclear fuel in surface facilities and monitoring and maintenance activities in the subsurface

Table 4-23. Estimated radiation doses and radiological health impacts to workers, each period and entire project.[a]

Worker group and impact category	Construction	Operation	Monitoring[b]	Closure	Entire project[c]
Maximally exposed worker					
Dose (rem)					
Involved	0.49	30	13	1.6	30
Noninvolved	0.052	0.32	0.21	0.028	0.32
Increase in probability of LCF					
Involved	0.00029	0.018	0.0078	0.0010	0.018
Noninvolved	0.000031	0.00019	0.00012	0.000017	0.00019
Worker population					
Collective dose (person-rem)					
Involved	33	5,800	890	400	7,100
Noninvolved	4.7	230	26	18	280
Nevada Test Site noninvolved	0.12	9.2	8.9	1.2	19
Totals[d]	38	6,000	930	420	7,400
Number of LCFs					
Involved	0.02	3.5	0.54	0.24	4.2
Noninvolved	0.0028	0.14	0.016	0.011	0.17
Nevada Test Site noninvolved	0.000074	0.0055	0.0053	0.00073	0.012
Totals[d]	0.023	3.6	0.56	0.25	4.4

a. Figure D-2 in Appendix D shows the projected worker population for each project period.
b. Doses are for 40-year monitoring period under active ventilation operating mode.
c. Maximally exposed worker doses are for the worker's entire working lifetime spanning the 50-year operations period. Population doses are for the entire 105-year project duration.
d. Totals might differ from sums due to rounding.
LCF = Latent cancer fatality.

facility. Exposure to the naturally occurring radioactive sources would account for 22 percent of the total worker dose. Inhalation of radon-222 and its decay products by subsurface workers would contribute 13 percent of the total dose, and ambient radiation exposure to subsurface workers would contribute 9 percent.

To put the 7,400 person-rem dose to the worker population in perspective, the same worker population, which represents about 86,000 full-time equivalent worker years, would receive 29,000 person-rem from the natural background radiation exposure of 340 millirem per year (Chapter 3, Section 3.1.8.1) over the entire project period of 105 years. Therefore, the addition of 7,400 person-rem would represent an increase of about 25% due to the Proposed Action. The estimated increase in number of latent cancer

fatalities that could occur in the repository workforce from the received radiation doses over the entire project would be 4.4. This can be compared to the 17 latent cancer fatalities that could result from the 29,000 person-rem that the same worker population would normally incur over the entire project period from exposure to natural background radiation.

Radiological Health Impacts to the Public for Entire Project

Table 4-24 (last column) lists the estimated radiation dose and potential radiological health impacts to the public for the entire project. Doses and radiological impacts would be for the offsite maximally exposed

Table 4-24. Estimated radiation doses and radiological health impacts to public, each period and entire project.[a,b]

Dose and health impact	Construction	Operations	Monitoring[c]	Closure	Entire project[d]
Maximally exposed individual[e]					
Maximum annual dose (millirem per year)	1.3	6.8	6.8	6.8	6.8
Total for period duration (millirem)	3.8	280	270	37	480
Probability of latent cancer fatality	2.3×10^{-6}	1.7×10^{-4}	1.6×10^{-4}	2.2×10^{-5}	2.9×10^{-4}
Exposed 80-kilometer population[f]					
Collective dose (person-rem)	85	6,400	6,100	840	13,000
Number of latent cancer fatalities	0.051	3.8	3.7	0.51	8

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. About 99.9 percent of the dose and impact would be from naturally occurring radon-222 and decay products.
b. Numbers are rounded to two significant figures; therefore, totals might differ from sums.
c. Doses are for 40-year monitoring period under active ventilation operating mode.
d. Doses are for the entire 105-year project duration.
e. At the southeast boundary of the analyzed land withdrawal area.
f. The projected population includes about 117,000 persons within 80 kilometers of the repository.

member of the public who resided continuously for 70 years at the site boundary location in the prevailing downwind direction. The increase in probability of a latent cancer fatality to this individual from exposure to radionuclides from the repository during the preclosure period would be about 0.0003. About 99.9 percent of the potential health impact would be from exposure to naturally occurring radon-222 and its decay products in subsurface exhaust ventilation air. The highest annual radiation dose would be 6.8 millirem, which is less than 4 percent of the annual average 200-millirem dose to members of the public from ambient levels of naturally occurring radon-222 and its decay products (Chapter 3, Section 3.1.8.2).

The estimated collective dose for the population within 80 kilometers (50 miles) for the entire project duration of 105 years would be 13,000 person-rem (Table 4-24). The corresponding number of latent cancer fatalities for this collective dose would be 8 in a projected population in 2067 of about 117,000 persons within 80 kilometers (50 miles) of the repository. For comparison, the analysis examined the number of expected cancer deaths that would occur from other causes in the same population during the same periods. The analysis calculated the expected number of cancer deaths that would not be related to the repository project on the basis of current statistics from the Centers for Disease Control and Prevention, which indicated that 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause during 1998 (DIRS_153066-Murphy 2000, p. 8). The comparison indicates that over the 105-year project duration the incremental chance of latent cancer fatalities among the projected population of about 117,000 would be about 2 in 10,000.

4.1.8 ACCIDENT AND SABOTAGE SCENARIO IMPACTS

This section describes the impacts from potential accident and sabotage scenarios for the Proposed Action. Section 4.1.8.1 discusses changes in the methods and data that DOE used to evaluate impacts from potential accidents since it completed the Yucca Mountain FEIS. Sections 4.1.8.2, 4.1.8.3, and 4.1.8.4 describe the analyses for radiological accident impacts, nonradiological accident impacts, and impacts from hypothetical sabotage events, respectively. DOE calculated impacts for (1) the *maximally* *exposed offsite individual,* (2) the *noninvolved worker,* and (3) the offsite population, which would include members of the public who resided within about 80 kilometers (50 miles) of the proposed repository. Because all waste handling operations would be remote, involved workers would be in enclosed facility operating rooms isolated from the waste. Involved workers would be unlikely to receive significant exposures to radioactive materials that an accident could release for the following reasons:

- For those releases that would occur within waste handling buildings (12 of the 14 accident scenarios), operators would be in enclosed operating areas that would isolate them from a release.
- For the fire scenario that would involve low-level radioactive waste, the fire would cause the release to be lofted into the atmosphere so that workers close to the release would not receive meaningful exposure.
- For the seismic scenario, workers inside the Low-level Waste Facility would likely be injured or killed as a result of the event, and the dose to the noninvolved worker at 60 meters (200 feet) would be representative of the dose to involved workers outside the facility. Appendix E contains details of the analysis method.

The impacts to offsite individuals from repository accidents under 95th-percentile weather conditions (conditions that result in doses that would only be exceeded 5 percent of the time) would be small, with calculated doses of 23 millirem or less to the maximally exposed offsite individual. Doses to a noninvolved worker would be higher than those to offsite individuals, up to 2.3 rem.

The accident analysis for this Repository SEIS is consistent with the preclosure safety analysis that DOE is finalizing for the compliance assessment in the application DOE intends to file with the NRC for construction authorization for the Yucca Mountain repository.

4.1.8.1 Changes Since Completion of the Yucca Mountain FEIS

Since it completed the Yucca Mountain FEIS, DOE has acquired new information and analytical tools that have contributed to the understanding of the potential impacts for accident analyses. The following sections describe the changes in potential accident impact analysis. Appendix E provides a more detailed evaluation of these changes.

4.1.8.1.1 *Commercial Spent Nuclear Fuel Characteristics*

The analysis for this Repository SEIS used a commercial pressurized-water reactor spent nuclear fuel assembly with the bounding radiological characteristics of 80,000 megawatt-days per metric ton of uranium burnup and a 5-year cooling time for accidents that would involve commercial spent nuclear fuel. This fuel bounds other commercial fuel types (boiling-water reactor and mixed-oxide spent fuel) because it would result in the highest accident scenario consequences. Appendix E, Section E.3 provides details.

4.1.8.1.2 *Population Distribution*

For this Repository SEIS, the projected duration of the operations period is 50 years, which would begin in 2017. The projected population for the 80-kilometer (50-mile) region of influence would be about 117,000 persons in 2067 (Chapter 3, Section 3.1.8, Table 3-16).

4.1.8.1.3 *Accident Analysis and Atmospheric Dispersion Models*

For this Repository SEIS, DOE used the GENII computer program to calculate radiation doses from a release of radioactive material (DIRS 100953-Napier et al. 1988, all). These calculations require site-specific dispersion factors (factors that measure the dilution of the downwind atmospheric plume). DOE used an NRC-developed atmospheric dispersion model to develop the dispersion factors. Appendix E, Section E.4.1 discusses the GENII program and the atmospheric dispersion model in more detail.

4.1.8.1.4 *Commercial Spent Nuclear Fuel Oxidation*

Additional information on fuel oxidation has become available since the completion of the Yucca Mountain FEIS. Fuel oxidation could occur during an accident if commercial spent nuclear fuel pellets at an elevated temperature were exposed to air. The oxidation would involve conversion of the uranium dioxide fuel pellet material into uranium oxide. Uranium oxide is a powder more respirable than the uranium dioxide fuel pellet material and would increase the downwind dose. For this Repository SEIS, if damaged commercial spent nuclear fuel was involved in an accident, the analysis, when appropriate, modeled that oxidation would contribute to the release over a period of 30 days. It also conservatively modeled that these accidents would occur without any measures to mitigate consequences (for example, evacuation or interdiction of food consumption) for this 30-day period to enable a conservative prediction of the radiological consequences. Appendix E, Section E.3.3.1 discusses fuel oxidation further.

4.1.8.1.5 *Radiation Dosimetry*

DOE changed the radiation dosimetry it used to evaluate consequences in this Repository SEIS to incorporate International Committee on Radiation Protection Publication 72 (DIRS 172935-ICRP 2001, all), the most recent dosimetry guidance available from the Committee. Appendix D, Section D.1 contains the details of this change.

4.1.8.1.6 *Latent Cancer Fatalities*

Current DOE guidance recommends that estimates of latent cancer fatalities be based on the received radiation dose and on radiation dose-to-health effect conversion factors recommended by the Interagency Steering Committee on Radiation Standards. For this Repository SEIS, DOE used the updated guidance for workers and members of the public, which is 0.0006 fatality per person-rem (DIRS 174559-Lawrence 2002, p. 2).

4.1.8.1.7 *Location of Maximally Exposed Offsite Individual*

In this Repository SEIS, the analysis used locations for the maximally exposed offsite individual of either 7.8 kilometers (4.8 miles) east of the repository or 18.5 kilometers (11 miles) southeast of the repository dependent on which location would receive the highest calculated dose from the specific accident scenario using the GENII program. Tables 4-25 and 4-26 later in this section specify the location for each accident. The analysis determined these locations as those that would produce the highest site boundary doses of any of the 16 radial sectors around the site based on sector specific dispersion factors that the GENII program uses to calculate doses. For the Yucca Mountain FEIS, the maximally exposed offsite individual was 11 kilometers (7.8 miles) to the west based on overall site average dispersion factors in the MACCS(2).

4.1.8.2 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material; they can include human-caused events such as aircraft crashes, external fires, and explosions and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and can include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. Last, it evaluated the consequences of the accident scenarios by estimating the potential radiation dose and radiological impacts.

The materials at risk for various accident scenarios could include several different types of radioactive materials—spent nuclear fuel from boiling- and pressurized-water commercial reactors in transportation, aging, and disposal (TAD) canisters or uncanistered fuel in transportation casks, DOE spent nuclear fuel canisters, naval spent nuclear fuel canisters, high-level radioactive waste canisters, and weapons-grade plutonium immobilized in a high-level radioactive waste glass matrix or as mixed-oxide fuel, both in canisters. Appendix A of the Yucca Mountain FEIS presented many details on the materials DOE would dispose of in the repository (DIRS 155970-DOE 2002, pp. A-1 to A-71).

Under the Proposed Action, up to 90 percent of the commercial spent nuclear fuel would arrive at the repository in TAD canisters. DOE would handle the remaining fuel as uncanistered spent fuel assemblies in the Wet Handling Facility and place it in TAD canisters for disposal. Appendix E, Section E.3 discusses materials at risk and the source terms DOE used for the accident analysis. In addition, the analysis examined accident scenarios that would involve the release of low-level waste that DOE generated and handled at the repository.

The analysis considered radiological consequences of the postulated accidents for the following:

- Noninvolved worker (collocated worker). A worker who would not be directly involved with material unloading, transfer, and emplacement activities, who DOE assumed to be 60 meters (200 feet) downwind of the facility where the release occurred. The 60-meter distance corresponds to the location of the exclusion fence around the waste handling buildings.

- Maximally exposed offsite individual. A hypothetical member of the public at a point on the site boundary who would be likely to receive the maximum dose. The analysis determined that the location with the highest potential exposure from an accidental release of radioactive material would be either (1) about 18 kilometers (11 miles) from the accident location (at the southeast boundary of the analyzed land withdrawal area), or (2) about 7.8 kilometers (4.8 miles) from the accident location (at the east boundary of the land withdrawal area).

- Offsite population. Members of the public within 80 kilometers (50 miles) of the repository site (Chapter 3, Section 3.1.8).

A review of the possible hazards and initiating events for the most current design concepts and planned operations identified 14 accident scenarios that DOE analyzed in detail. They included accidents in the Initial Handling Facility, the Wet Handling Facility, a Canister Receipt and Closure Facility, the Receipt Facility, and the Low-Level Waste Facility. The accident scenarios considered drops and collisions that involved shipping casks, TAD canisters, dual-purpose canisters, and uncanistered fuel assemblies, a fire that involved low-level radioactive waste, and a seismic event. DOE analyzed the scenarios under average (50th-percentile) meteorological conditions (conditions that result in average doses over the spectrum of possible weather conditions) and unfavorable (95th-percentile) meteorological conditions (conditions that result in higher doses that would be exceeded only 5 percent of the time). Appendix E, Section E.2 contains detail of the analysis. For this Repository SEIS, DOE did not evaluate the seismic collapse of a waste handling building that was evaluated in the Yucca Mountain FEIS because DOE intends to enhance the capability of the buildings to withstand ground motion associated with seismic events. In addition, the transporter runaway accident that was analyzed in the Yucca Mountain FEIS was not evaluated in this SEIS because the event was found to be not credible based on the modified design of the vehicle that would transport waste to the emplacement drifts. Details are provided in Appendix E, Sections E.2.1.2.2 and E.2.1.1.8.

Tables 4-25 and 4-26 list the results of the radiological accident scenarios DOE modeled for this Repository SEIS for 95th-percentile and 50th-percentile meteorological conditions, respectively. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from these exposure pathways and from long-term external exposure to radionuclides the plume deposited on soil during passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis assumed neither DOE nor other government agencies would implement mitigation measures, such as evacuation, to limit long-term radiation doses.

The accident scenarios with the highest consequences in Table 4-25 would involve either (1) a seismic event that caused the release of radioactive material from high-efficiency particulate air filters, ducts, and low-level radioactive waste, or (2) a drop and breach of a dual-purpose canister that contained 36 pressurized-water reactor spend nuclear fuel assemblies. The estimated health impacts to the offsite population would be 0.16 additional latent cancer fatalities in the exposed population of 104,000 in the sector with the largest population (south-southeast) for the 95th-percentile weather condition. The maximum dose to the maximally exposed noninvolved worker could be 2.3 rem, which would result in an increased probability of a latent cancer fatality to the individual of 0.0014.

4.1.8.3 Nonradiological Accidents

A potential release of hazardous or toxic materials would be minimal because the repository would not accept hazardous waste under the *Resource Conservation and Recovery Act* (42 U.S.C. 6901 et seq.). However, some potentially hazardous metals, such as arsenic or mercury, could be present in the high-level radioactive waste inventory. Nonradioactive hazardous or toxic substances, such as cleaning solvents, sodium hydroxide, sulfuric acid, and solid chemicals, would be present in limited quantities at the repository as part of operational requirements. Impacts to members of the public would be unlikely due to the limited quantities and because the chemicals would be mostly liquid and solid, so a release would be confined to the site. The generation, storage, and offsite shipment of solid and liquid hazardous wastes from operations would represent minimal incremental risk from accidents. Section 4.1.7 describes

Table 4-25. Estimated radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) sector-specific meteorological conditions.

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
1. Drop of, or equipment drop on, naval canister with breach	1.7×10^{-2} (3.4×10^{-4})	2.0×10^{-4} (4.6×10^{-2})[c]	1.2×10^{-7}	5.4×10^{0} (4.0×10^{2})[c]	3.2×10^{-3}	1.5×10^{-2} (5.6×10^{0})[c]	9.0×10^{-6}
2. Drop with breach of HLW canisters in transportation cask	2.1×10^{-2} (4.2×10^{-4})	2.4×10^{-5} (2.4×10^{-3})[c]	1.4×10^{-8}	2.0×10^{-1} (2.0×10^{1})[c]	1.2×10^{-4}	3.2×10^{-3} (3.2×10^{-1})[c]	1.9×10^{-6}
3. Drop of HLW in an unsealed waste package or drop of equipment on HLW with breach	9.8×10^{-2} (2.0×10^{-3})	2.4×10^{-4} (2.4×10^{-2})[c]	1.4×10^{-7}	2.0×10^{3} (2.0×10^{5})[c]	1.2×10^{-3}	3.2×10^{-2} (3.2×10^{4})[c]	2.0×10^{-5}
4. Drop with breach of HLW canister during transfer	2.1×10^{-1} (4.2×10^{-3})	9.6×10^{-5} (9.6×10^{-3})[c]	5.8×10^{-8}	8.0×10^{-1} (8.0×10^{1})[c]	4.8×10^{-4}	1.3×10^{-2} (1.3×10^{0})[c]	7.8×10^{-6}
5. Drop of transportation cask with breach of PWR assemblies	8.7×10^{-2} (1.7×10^{-3})	1.2×10^{-3}	7.2×10^{-7}	3.0×10^{-5}	1.8×10^{-2}	1.9×10^{-1}	1.1×10^{-4}
6. Drop of inner lid of transportation cask of PWR assemblies with breach in water	4.4×10^{-2} (8.8×10^{-4})	9.2×10^{-4}	5.5×10^{-7}	2.5×10^{1}	1.5×10^{-2}	5.2×10^{-2}	3.1×10^{-5}
7. Drop of, or drop of equipment on, DPC with breach	5.7×10^{-2} (1.1×10^{-3})	1.1×10^{-2}	6.6×10^{-6}	2.7×10^{2}	1.6×10^{-1}	1.7×10^{0}	1.0×10^{-3}
8. Drop of, or drop of equipment on, DPC with breach in water	2.1×10^{-2} (4.2×10^{-4})	8.2×10^{-3}	4.9×10^{-6}	2.3×10^{2}	1.4×10^{-1}	4.6×10^{-1}	2.8×10^{-4}
9. Drop with breach of TAD canister	5.0×10^{-1} (1.0×10^{-2})	6.4×10^{-3}	3.8×10^{-6}	1.6×10^{2}	9.6×10^{-2}	1.0×10^{0}	6.0×10^{-4}

Table 4-25. Estimated radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) sector-specific meteorological conditions (continued).

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
10. Drop of lid into TAD canister in water with breach of fuel assemblies	1.7×10^{-2} (3.4×10^{-4})	4.8×10^{-3}	2.9×10^{-6}	1.3×10^{2}	7.8×10^{-2}	2.7×10^{-1}	1.6×10^{-4}
11. Drop with breach of fuel assembly in water	4.8×10^{-2} (9.6×10^{-3})	4.6×10^{-4}	2.7×10^{-7}	1.3×10^{1}	7.8×10^{-3}	2.6×10^{-2}	1.6×10^{-5}
12. Collision or drop of equipment on fuel assembly in water with breach	4.8×10^{-1} (9.6×10^{-3})	2.3×10^{-4}	1.4×10^{-7}	6.3×10^{0}	3.8×10^{-3}	1.3×10^{-2}	7.8×10^{-6}
13. Fire involving LLW	5.0×10^{-1} (1.0×10^{-2})	6.2×10^{-6}	3.7×10^{-9}	4.9×10^{-2}	2.9×10^{-5}	4.0×10^{-4}	2.4×10^{-7}
14. Seismic event involving failure of HEPA system and LLW confinement	$<1.0 \times 10^{-4}$ ($<2.0 \times 10^{-6}$)	2.3×10^{1}	1.4×10^{-8}	1.9×10^{2}	1.1×10^{-1}	2.3×10^{0}	1.4×10^{-3}

a. Assumed to be at the analyzed land withdrawal boundary either in the east sector (7.8 kilometers or 4.8 miles) or in the southeast sector (18.5 kilometers or 11 miles), whichever produces the highest site boundary dose. For accident scenarios 6, 8, 10, 11 and 12, DOE calculated the highest dose for the southeast sector. For all other accident scenarios, DOE calculated the highest dose for the east sector.

b. LCF_i is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose (rem). LCF_p is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose to LCFs as discussed in Section E.4.1.

c. Unfiltered doses presented to illustrate that filtration systems might not be required in the Initial Handling Facility to meet regulatory standards.

DPC = Dual-purpose canister.
HEPA = High-efficiency particulate air.
HLW = High-level radioactive waste.
LCF = Latent cancer fatality.
LLW = low-level radioactive waste.
PWR = Pressurized-water reactor.
TAD = Transportation, aging, and disposal (canister).

Table 4-26. Estimated radiological consequences of repository operations accident scenarios for annual average (50th-percentile) sector-specific meteorological conditions.

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
1. Drop of, or equipment drop on, naval canister with breach	1.7×10^{-2} (3.4×10^{-4})	3.1×10^{-6}	1.9×10^{-9}	3.6×10^{-2}	2.2×10^{-5}	2.4×10^{-3}	1.4×10^{-6}
2. Drop with breach of HLW canisters in transportation cask	2.1×10^{-2} (4.2×10^{-4})	4.1×10^{-7}	2.5×10^{-10}	1.4×10^{-3}	8.4×10^{-7}	5.3×10^{-4}	3.2×10^{-7}
3. Drop of HLW canisters in an unsealed waste package or drop of equipment on HLW canisters with breach	9.8×10^{-2} (2.0×10^{-3})	4.1×10^{-6}	2.5×10^{-9}	1.4×10^{-2}	8.4×10^{-6}	5.3×10^{-3}	3.2×10^{-6}
4. Drop with breach of HLW canisters during transfer	2.1×10^{-1} (4.2×10^{-3})	1.6×10^{-6}	9.6×10^{-10}	5.6×10^{-3}	3.4×10^{-6}	2.1×10^{-3}	1.3×10^{-6}
5. Drop of transportation cask with breach of PWR assemblies	8.7×10^{-2} (1.7×10^{-3})	7.2×10^{-5}	4.3×10^{-8}	5.6×10^{-1}	3.4×10^{-4}	8.3×10^{-2}	5.0×10^{-5}
6. Drop of inner lid of transportation cask of PWR assemblies with breach in water	4.4×10^{-2} (8.8×10^{-4})	1.1×10^{-5}	6.6×10^{-9}	1.5×10^{-1}	9.0×10^{-5}	8.4×10^{-3}	5.0×10^{-6}
7. Drop of, or drop of equipment on, DPC with breach	5.7×10^{-2} (1.1×10^{-3})	6.5×10^{-4}	3.9×10^{-7}	5.0×10^{0}	3.0×10^{-3}	7.5×10^{-1}	4.5×10^{-4}
8. Drop of, or drop of equipment on, DPC with breach in water	2.1×10^{-2} (4.2×10^{-4})	1.0×10^{-4}	6.0×10^{-8}	1.4×10^{0}	8.4×10^{-4}	7.6×10^{-2}	4.6×10^{-5}
9. Drop with breach of TAD canister	5.0×10^{-1} (1.0×10^{-2})	3.8×10^{-4}	2.3×10^{-7}	2.9×10^{0}	1.7×10^{-3}	4.4×10^{-1}	2.6×10^{-4}

Table 4-26. Estimated radiological consequences of repository operations accident scenarios for annual average (50th-percentile) sector-specific meteorological conditions (continued).

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
10. Drop of lid into TAD canister in water with breach of fuel assemblies	1.7×10^{-2} (3.4×10^{-4})	5.9×10^{-5}	3.5×10^{-8}	7.7×10^{-1}	4.8×10^{-4}	4.4×10^{-2}	2.6×10^{-5}
11. Drop with breach of fuel assembly in water	4.8×10^{-2} (9.6×10^{-3})	5.6×10^{-6}	3.4×10^{-9}	7.4×10^{-2}	4.4×10^{-5}	4.2×10^{-3}	2.5×10^{-6}
12. Collision or drop of equipment on fuel assembly in water with breach	4.8×10^{-2} (9.6×10^{-3})	2.8×10^{-6}	1.7×10^{-9}	3.7×10^{-2}	2.3×10^{-5}	2.1×10^{-3}	1.3×10^{-6}
13. Fire involving LLW	5.0×10^{-1} (1.0×10^{-2})	1.2×10^{-7}	7.2×10^{-11}	4.4×10^{-4}	2.6×10^{-7}	6.6×10^{-5}	4.0×10^{-8}
14. Seismic event involving failure of HEPA system and LLW confinement	$<1.0 \times 10^{-4}$ ($<2.0 \times 10^{-6}$)	4.4×10^{-4}	2.6×10^{-7}	1.6×10^{0}	9.6×10^{-4}	3.7×10^{-1}	2.2×10^{-4}

a. Assumed to be at the analyzed land withdrawal boundary in the east sector, which would produce the highest site boundary dose at a distance of 7.8 kilometers (4.8 miles).

b. LCF_i is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose (rem). LCF_p is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose to LCFs as discussed in Section E.4.1.

DPC = Dual-purpose canister.
HEPA = high-efficiency particulate air.
HLW = High-level radioactive waste.
LCF = Latent cancer fatality.
LLW = low-level radioactive waste.
PWR = Pressurized-water reactor.
TAD = Transportation, aging, and disposal (canister).

potential impacts to workers from normal industrial hazards in the workplace (which would include industrial accidents). DOE derived the statistics in the analysis from accident experience at other sites.

4.1.8.4 Sabotage

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the United States Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements to prevent terrorists from gaining control of commercial aircraft, such as (1) more stringent screening of airline passengers and baggage by the Transportation Security Administration, (2) increased presence of Federal Air Marshals on many flights, (3) improved training of flight crews, and (4) hardening of aircraft cockpits. Additional measures have been imposed on foreign passenger carriers and domestic and foreign cargo carriers, as well as charter aircraft.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (before closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

NRC regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level radioactive waste do not constitute an unreasonable risk to public health and safety." The regulations require the storage of spent nuclear fuel and high-level radioactive waste in a protected area such that:

- Access to the material would require passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, to be continually monitored, and to be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

NRC regulations would require a trained, equipped, and qualified security force to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. NRC requires liaison with response forces to permit timely response to unauthorized entry or activities. In addition, the NRC requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location sufficiently remote from the original records that a single event would not destroy both sets of records.

Although it is difficult to predict if sabotage events would occur, and the nature of such events if they were to occur, in response to public comments and to evaluate a scenario that would approximate the consequences of a major sabotage event, DOE analyzed a hypothetical scenario in which a large commercial jet aircraft would crash into and penetrate the repository facility with the largest inventory of radioactive material vulnerable to damage from such an event.

The analysis conservatively modeled that the aircraft impact would compromise the confining capability of the building and the resulting fire would convert 42 spent nuclear fuel assemblies to an oxide powder. The results of this analysis indicate that the maximally exposed offsite individual could receive a dose of 4.0 rem resulting in an estimated likelihood of a latent cancer fatality of 0.0024, and the offsite public in the highest population sector (south-southeast), which in 2067 would consist of an estimated 104,000 individuals, could receive a collective dose of 13,000 person-rem for average weather conditions resulting in an estimated 7.8 latent cancer fatalities. Appendix E, Section E.7 contains details of the analysis.

4.1.9 NOISE AND VIBRATION IMPACTS

This section describes potential noise and vibration impacts to workers (occupational noise) and to the public (nuisance noise) from activities under the Proposed Action. The region of influence for noise and vibration impacts includes the Yucca Mountain site and existing and future residences to the south in the town of Amargosa Valley. Section 4.1.9.1 summarizes and incorporates by reference the noise impacts from construction, operation and monitoring, and closure of the repository in Section 4.1.9.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 4-70). Section 4.1.9.2 and Section 4.1.9.3 provide new analyses based on the current design and operational plan. Section 4.1.9.2 discusses noise impacts from construction of the access road from U.S. Highway 95 and the offsite facilities that DOE would build south of the analyzed land withdrawal area. Section 4.1.9.3 discusses impacts from vibration. Section 4.1.4.1.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise impacts in the analyzed land withdrawal area during the construction phase would include activities at the site development areas that involved heavy equipment (for example, bulldozers, graders, loaders, cranes, and pavers), ventilation fans, and diesel generators. Sources of noise during the operations and monitoring periods would include diesel generators, cooling towers, ventilation fans, air conditioners, and concrete batch plant activities. Ventilation fans would have noise suppressors that would maintain noise levels below 85 A-weighted decibels (dBA) at a distance of 3 meters (10 feet). The Occupational Safety and Health Administration standard for the maximum permissible continuous noise level for workers, without the

> **DECIBELS**
>
> **A-weighted decibels (dBA):** A measurement of sound that approximates the sensitivity of the human ear, which is used to characterize the intensity or loudness of sound.
>
> **Vibration velocity decibels (VdB):** Vibration velocity in decibels with respect to 1 micro-inch per second. A measurement of root-mean-square velocity for the evaluation of ground vibration as an average or smoothed vibration amplitude on a logarithmic scale.

use of controls, is 90 dBA for a duration of 8 hours per day [29 CFR 1910.95(b)(2)]. The regulation, in calculating the permissible exposure level, uses a 5 dB time-over-intensity trading relationship, or exchange rate. For a person to be exposed to noise levels of 95 dBA, the permissible amount of time at this exposure level must be halved to be within the permissible exposure level. Conversely, a person who is exposed to 85 dBA is allowed twice as much time at this level (16 hours). The National Institute for Occupational Safety and Health and the American Conference of Governmental Industrial Hygienists both recommend an exposure limit of 85 dBA for an 8-hour exposure, with a 3-dB exchange rate. Therefore, a worker can be exposed to 85 dBA for 8 hours, but to 88 dBA for only 4 hours or 91 dBA for only 2 hours.

The point on the boundary of the analyzed land withdrawal area nearest to noise sources at the North Portal area would be about 11 kilometers (7 miles) due west. The distance and direction from the South Portal development area to the nearest point on the boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) due west.

To establish the propagation distance of repository-generated noise for this analysis, DOE used a maximum sound level of 132 dBA. It is unlikely that construction activities would generate noise at this high level. For comparison, heavy trucks generate sound levels of 70 to 80 dBA at 15 meters (50 feet). However, the analysis determined that this high level of noise would attenuate to the lower limit of human hearing (20 dBA) at a distance of 6 kilometers (3.7 miles). Therefore, noise impacts to the public would be unlikely outside the analyzed land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical individual at the land withdrawal area boundary would be large enough to reduce the noise to background levels or below, and because there would be no residential or community receptors at the boundary [the nearest housing is in the town of Amargosa Valley about 22 kilometers (14 miles) from the repository site], DOE expects no noise impacts to the public due to activities at Yucca Mountain under the Proposed Action.

Construction noise is transitory in nature. At times, workers at the repository site would be exposed to elevated levels of noise. Small impacts to workers such as speech interference and annoyance would occur. However, DOE would control noise levels and worker exposures such that impacts (such as hearing loss) would be unlikely. Engineering controls would be the primary method of noise control. Workers would use personal hearing protection as necessary to supplement engineering controls.

Noise impacts during the closure period would be similar to those during construction and operations.

4.1.9.2 Noise Impacts from Construction of Offsite Infrastructure

Sources of noise impacts outside the analyzed land withdrawal area would include construction of the access road from U.S. Highway 95 and multiple facilities south of the Yucca Mountain site near Gate 510. Offsite facilities would include the Sample Management Facility, a training facility, a marshalling yard and warehouse, and temporary housing for construction workers. Construction activities would involve typical construction equipment (for example, bulldozers, graders, loaders, and pavers). This type of construction equipment generates noise levels of about 85 dBA at 15 meters (50 feet). Noise and sound levels would be typical of new construction activities and would be intermittent. The nearest permanent residents would be in the town of Amargosa Valley, which is southwest of the intersection of

U.S. Highway 95 and Nevada State Route 373. The closest offsite construction activities to the residents would take place at this intersection where DOE would relocate the current Gate 510 road intersection with U.S. Highway 95 to line up with the intersection of State Route 373 and U.S. Highway 95. Because of the distance between construction activities and receptors and the temporary and intermittent nature of construction noise, DOE does not anticipate noise impacts to the public from construction of the access road or offsite facilities.

Traffic noise on the access road would not exceed or significantly add to the existing traffic noise on U.S. Highway 95. Noise from operation of the offsite facilities would be typical of commercial environments and would not cause impacts.

4.1.9.3 Vibration Impacts from Construction, Operation and Monitoring, and Closure

Construction activity can result in various degrees of ground vibration dependent on the equipment and construction methods. Construction equipment causes ground vibrations that spread through the ground and diminish in strength with distance. Activities that typically generate the most severe vibrations are blasting and impact pile driving. DOE could use blasting in the excavation of the shafts and the turnouts to the emplacement drifts. Blasting activity results in a typical velocity level of slightly less than 100 VdB at 15 meters (50 feet). Use of bulldozers and other heavy tracked construction equipment results in typical velocity levels around 93 VdB at 15 meters. However, generalized surface vibration curves show that a vibration with a velocity level of 95 VdB at 3.3 meters (10 feet) drops to a velocity level of 67 VdB at 91 meters (300 feet). The approximate threshold for human perception of vibration is 65 VdB (DIRS 177297-Hanson et al. 2006, all). The point on the analyzed land withdrawal boundary closest to blasting activity would be about 7 kilometers (4 miles) due west. Ground-borne vibration during the operations, monitoring, and closure periods would be imperceptible at the boundary. Because of the large distances between Proposed Action activities and sensitive structures, there would be no adverse vibration impacts.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from the Proposed Action. The region of influence for aesthetics includes the approximate boundary of the analyzed land withdrawal area, an area west of the boundary where ventilation stacks could be seen, and the area south of the boundary where DOE would construct the access road from U.S. Highway 95 and several offsite facilities. The analysis considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. It gave specific consideration to scenic quality, visual sensitivity, and distance from observation locations. This section provides a new analysis of the aesthetic impacts of the Proposed Action.

4.1.10.1 Approach

Because of the limited visibility of Yucca Mountain from publicly accessible locations, DOE identified two general locations from which the public could see facilities: one to the south of the repository near the intersection of Nevada State Route 373 and U.S. Highway 95, and the other to the west of the repository where repository ventilation exhaust stacks could be visible. There would be no public access to the north or east of the site to enable viewing of the facilities. DOE used the Bureau of Land Management criteria in Table 4-27 to rate the predicted contrast between existing conditions and

Table 4-27. Criteria for determining degree of contrast.

Degree of contrast	Criteria
None	The element contrast is not visible or perceived.
Weak	The element contrast can be seen but does not attract attention.
Moderate	The element contrast begins to attract attention and begins to dominate the characteristic landscape.
Strong	The element contrast demands attention, will not be overlooked, and is dominant in the landscape.

Source: DIRS 173053-BLM 1986, Section III.D.2.a.

conditions DOE expects from the Proposed Action at the two locations. To determine potential aesthetic impacts, the analysis then considered if the predicted contrast at these locations would be consistent with the Bureau of Land Management visual resource management objectives in Table 4-28. Dependent on the visual resource management objective for a particular location, various levels of contrast are acceptable.

Table 4-28. Bureau of Land Management visual resource management classes and objectives.

Visual resource class	Objective	Acceptable changes to land
Class I	Preserve the existing character of the landscape.	Provides for natural ecological changes but does not preclude limited management activity. Changes to the land must be small and must not attract attention.
Class II	Retain the existing character of the landscape.	Management activities can be seen but should not attract the attention of the casual observer. Changes must repeat the basic elements of form, line, color, and texture of the predominant natural features of the characteristic landscape.
Class III	Partially retain the existing character of the landscape.	Management activities can attract attention but cannot dominate the view of the casual observer. Changes should repeat the basic elements in the predominant natural features of the characteristic landscape.
Class IV	Provide for management activities that require major modifications of the existing character of the landscape.	Management activities can dominate the view and be the major focus of viewer attention. An attempt should be made to minimize the impact of activities through location, minimal disturbance, and repeating the basic elements.

Source: DIRS 101505-BLM 1986, Section V.B.

4.1.10.2 Aesthetic Impacts from Construction, Operation and Monitoring, and Closure

The low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near the intersection of Nevada State Route 373 and U.S. Highway 95 (location 1), approximately 22 kilometers (14 miles) away. Therefore, from this location, the proposed repository would cause a weak degree of contrast that is consistent with the management of the Class III lands that surround U.S. Highway 95 (Figure 4-8).

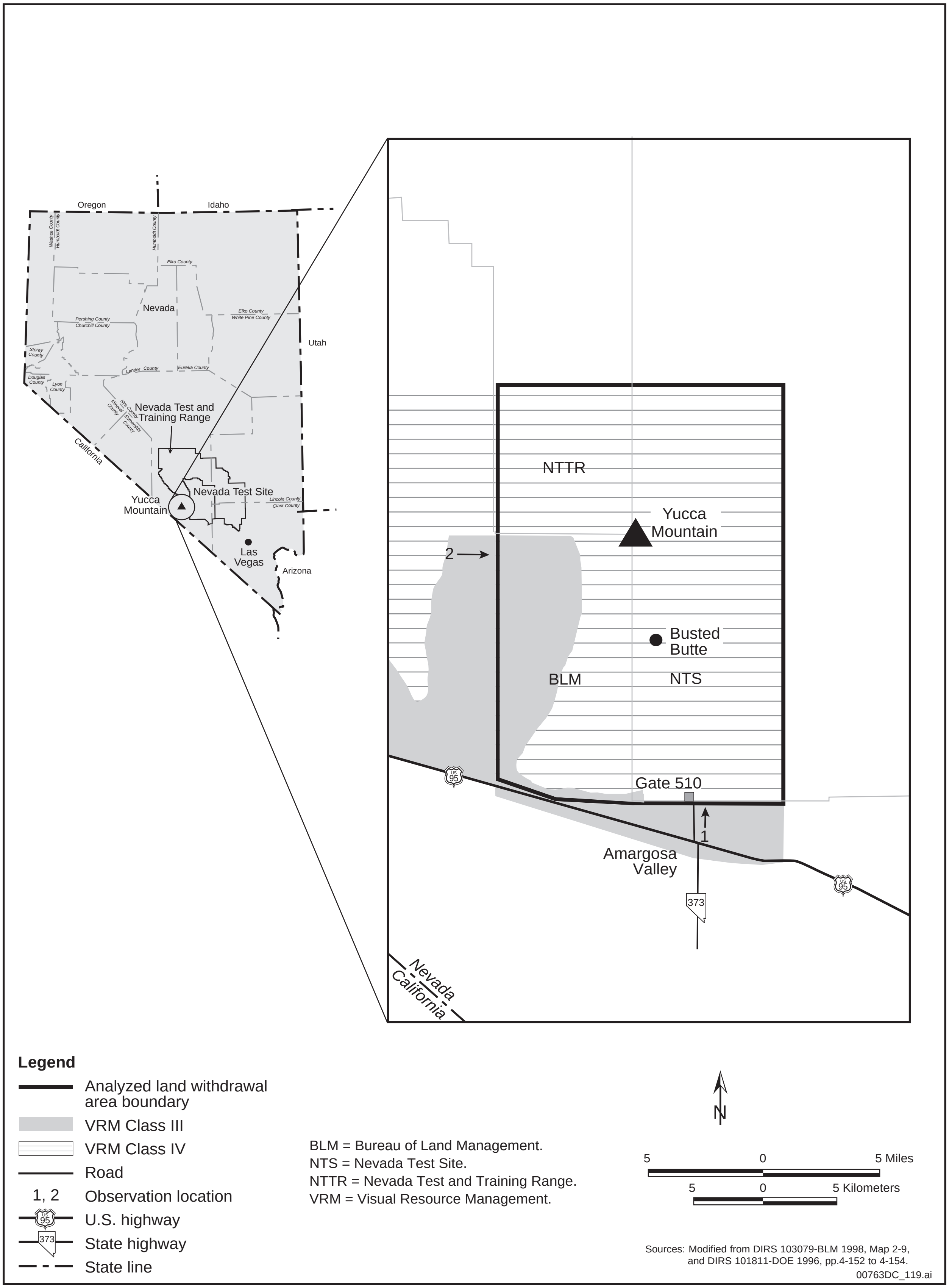


Figure 4-8. Visual resource management classifications in potentially affected areas.

During construction of the access road from U.S. Highway 95 and offsite facilities south of the analyzed land withdrawal boundary, construction-related equipment, facilities, and activities would be potential sources of impacts to visual resources. The presence of workers, vehicles, equipment, temporary accommodations for construction workers, and the generation of dust and vehicle exhaust could be visible or could attract the attention of a casual observer at location 1. Considering the effect of best management practices for construction projects, construction activities would be noticeable but would not dominate the attention of a viewer and, therefore, would create a weak degree of contrast at this location.

A weak degree of contrast is compatible with the Bureau of Land Management objectives for all classes of lands and would cause small project-related visual impacts during construction of the access road and offsite facilities.

The new access road would intersect U.S. Highway 95 approximately 0.39 kilometer (0.24 mile) to the southeast of the existing access road intersection with U.S. Highway 95 and would line up with the existing intersection of Nevada State Route 373 and U.S. Highway 95. DOE would use simple acceleration and deceleration lanes at the new intersection. Only about 0.049 square kilometer (12 acres) of new land would be necessary for the intersection and approximately 0.097 square kilometer (24 acres) would be necessary for 1.6 kilometers (1 mile) of new road that would be 61 meters (200 feet) wide. The temporary accommodations would occupy about 0.1 square kilometer (25 acres) and would include housing for construction workers; a utility zone for power supply, temporary trash storage, wastewater, and potable water treatment; eating facilities; laundry facilities; and office space. DOE would use gravel fill for roads and parking areas and would install lighting for security and parking. The most visible structures would be the housing facilities. The training facility would require approximately 0.02 square kilometer (5 acres) of land for the facility and associated parking, landscaping, and access. The Sample Management Facility would require approximately 0.012 square kilometer (3 acres). The marshalling yard and warehouse would require some fencing, offices, warehousing, open laydown, and shops on approximately 0.2 square kilometer (50 acres). The access road and offsite facilities would cause a weak degree of contrast against the landscape passing motorists could observe. A weak degree of contrast is consistent with the management of the Class III lands that surround U.S. Highway 95 and would result in small impacts to the visual setting. DOE would remove the temporary accommodations for construction workers and reclaim disturbed areas after they were no longer necessary.

The only structures that could be visible from the west (location 2) and exceed the elevation of the southern ridge of Yucca Mountain would be the ventilation exhaust shafts. The ventilation system would include intake and exhaust stacks, support structures, and access roads near the crest of Yucca Mountain on 0.24 square kilometer (60 acres) of land. The construction of pads and roads to the pads would be on 0.08 square kilometer (20 acres) of undisturbed land. The remaining 0.16 square kilometer (40 acres) is existing disturbed dirt roads that would access these locations. The design includes three intake shafts and six exhaust shafts. The exhaust shafts would contain 15- to 18-meter (50- to 60-foot) stacks. The height of the ventilation intake structures would be lower than the exhaust stacks, and DOE would build these structures at lower elevations. Therefore, the intake stacks would not be as likely as the exhaust stacks to cause aesthetic impacts. The presence of exhaust ventilation stacks on the crest of Yucca Mountain would be seen as an adverse aesthetic impact by American Indians and would cause a moderate degree of contrast. Because of the height of the ventilation stack structures at the top of Yucca Mountain, the U.S. Air Force might require flashing beacon lights at the tops of the stacks. Such beacons could be visible for several miles, especially west of Yucca Mountain, but would not be visible in Death Valley National Park.

DOE would provide lighting for operations areas at the proposed repository and at the offsite facilities. Lighting would be typical for commercial properties except there would be no advertising lighting. Outdoor lighting would be high-intensity-discharge, sodium-vapor lights for roadways, perimeter fencing, and area lighting. Lighting levels would be as low as possible to save operating costs and avoid degradation of the dark character of the night sky, but high enough for security. Repository lighting could be visible outside the analyzed land withdrawal area, especially from the west (location 2) due to the ventilation structures at the top of Yucca Mountain. Repository lighting would be unlikely to affect users of Death Valley National Park. Because the towns of Amargosa Valley, Beatty, and Pahrump lie between the park and the repository, they probably would cause greater impact to the nightly viewshed than operations lighting at the repository. Lighting at the offsite facilities would be visible from location 1 near the intersection of Nevada State Route 373 and U.S. Highway 95. The use of shielded or directional lighting as a best management practice would minimize the amount of light that could be visible from outside the lighted areas and mitigate light pollution and the degradation of the dark character of the night sky. Overall, impacts from lighting would be small.

Closure activities, such as dismantling of facilities and site reclamation, would reduce the project-related contrast. Adverse impacts to visual quality from closure activities would be unlikely.

4.1.11 Impacts to Utilities, Energy, Materials, and Site Services

This section updates the potential impacts to residential water and sewer, energy, materials, and site services from construction, operations, monitoring, and closure activities at the proposed repository. DOE has reanalyzed impacts to utilities, energy, materials, and site services for this Repository SEIS based on the modified design that Chapter 2 describes. The scope of the analysis included the use of electric power; fossil fuels, oil and lubricants; construction materials; and onsite services such as emergency medical support, fire protection, and security and law enforcement. The analysis compared needs to available capacity. It used engineering estimates of requirements for construction materials, utilities, and energy. Construction activities would occur during the construction and operations periods. The region of influence includes the local, regional, and national infrastructure that would supply the needs.

Section 4.1.14 discusses impacts in relation to TAD canister, waste package, and drip shield fabrication. Overall, DOE expects only small impacts from demand on residential water and sewer, energy, materials, and site services from the Proposed Action.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operations, Monitoring, and Closure

4.1.11.1.1 *Residential Water*

The repository facilities would not use water utilities from outside the analyzed land withdrawal area. DOE would use permitted wells to supply water for repository activities. DOE could build facilities (including the Sample Management Facility, training facility, marshalling yard, and warehouse) outside the land withdrawal area and would evaluate the most appropriate water sources once the locations and designs were final.

Population growth that resulted from the Proposed Action could affect regional water resources. The Proposed Action would result in an estimated maximum population increase in Clark County of approximately 1,300 persons in 2034 and an estimated maximum population increase in Nye County of approximately 1,000 persons in 2039. Other counties would be unlikely to have measurable population increases as a result of the Proposed Action. (Section 4.1.6 describes the estimated maximum population increases in Clark and Nye counties in greater detail.) Whether predominantly surface-water sources, as is the case for most of Clark County, or groundwater sources, as for most of Nye County, satisfied domestic water needs, these relatively small increases in population would have small impacts on existing water demands.

The maximum project-related population increase for Clark County would be less than 0.07 percent of the baseline 2005 population of 1.8 million and less than 0.04 percent of the county's estimated population in 2034, the year of the maximum population impact from the Proposed Action (Chapter 3, Section 3.1.7). The associated increase in water demand in the county as a result of the project would be correspondingly small.

The maximum project-related population increase for Nye County would be less than 3 percent of the baseline 2005 population of 41,000 and about 1.2 percent of the county's estimated population in 2039, the year of the maximum population impact from the Proposed Action (Chapter 3, Section 3.1.7). For Nye County, estimates of domestic water demand from public water supplies are about 1.3 cubic meters (350 gallons) per day per person (DIRS 173226-Buqo 2004, p. 48). At this rate, the project-related increase in Nye County population would result in an additional water demand of about 500,000 cubic meters (410 acre-feet) of water during the maximum year (2039). This represents about 0.4 percent of the total water use of 120 million cubic meters (101,000 acre-feet) in Nye County in 2000. If 100 percent of the project-related growth in Nye County occurred in Pahrump (the upper bound condition), this would equate to adding about 500,000 cubic meters to Pahrump's annual water demand. This represents about 1.8 percent of the 2000 Pahrump Valley total water use of 28 million cubic meters (23,000 acre-feet). By 2039, when project-related population growth would peak, Pahrump Valley's water demand will have increased above its 2000 level due to growth unrelated to the Proposed Action. The project-related increase in water demand of 500,000 cubic meters would be an even smaller percentage of the total Nye County and Pahrump water usage in 2039 than in 2000.

4.1.11.1.2 *Residential Sewer*

The repository facilities would not use sewer utilities from outside the analyzed land withdrawal area. DOE would use septic tanks and leach fields for the sanitary waste system.

Population growth due to the Proposed Action could affect sewer utilities. In Clark County, the maximum project-related population increase would be less than 0.07 percent of the 2005 baseline population. Impacts to the populous areas of the county such as the Las Vegas Valley would be small.

In Nye County, the maximum project-related population increase (in 2039) would be less than 3 percent of the 2005 baseline population. Growth in Nye County from the Proposed Action would likely be primarily in the Pahrump area. Pahrump has no community-wide wastewater treatment system. Individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

4.1.11.1.3 *Electric Power*

During the construction period, the demand for electricity would increase as DOE operated tunnel boring machines and other electrical equipment. The estimated peak demand for electric power during the construction period would be about 30 megawatts. The construction of the tunnels and drifts would account for more than 60 percent of the demand due to the use of four tunnel boring machines. Table 4-29 lists projected electric energy use during the different analytical periods.

Table 4-29. Electricity and fossil-fuel use for the Proposed Action.

Analytical period	Use (years)
Construction	5
Operations	up to 50
Monitoring	50
Closure (overlaps last 10 years of Monitoring)	10
Total	up to 105
Peak electric power	(megawatts)
Construction[a]	30
Operations[a]	90
Monitoring[b]	7.7
Closure[b]	10
Maximum	90
Electricity use: annual maximum	(1,000 megawatt-hours)
Construction	260
Operations[a]	790
Monitoring[c]	63
Closure[c]	72
Maximum	790
Fossil fuel	(million liters)
Construction[d,e]	19
Operations[d,e]	690
Monitoring[e]	53
Closure[b]	5.2
Total	770
Oils and lubricants[b]	(million liters)
Construction	2.6
Operations	8.5
Monitoring	9
Closure	2
Total	22

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Source: DIRS 182197-Morton 2007, all.
b. Source: DIRS 155970-DOE 2002, p. 4-73.
c. Calculated based on average usage per year as stated in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 4-73).
d. Source: DIRS 182211-Morton 2007, p. 2.
e. Source: DIRS 182210-Morton 2007, all.

The current electric power supply line has a peak capacity of only 10 megawatts. Upgrades to the site electrical system are part of the Proposed Action.

During the operations period, the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be about

90 megawatts. Full operation of the repository would account for about 70 megawatts while construction of the drifts would account for the remaining 20 megawatts. The maximum annual electric power use would be about 790,000 megawatt-hours.

After the completion of excavation activities, the peak demand for electric power would drop to about 70 megawatts. The peak demand would continue to decrease after the operations period. The peak demand during the monitoring period would be much less than the 70-megawatt demand during operations. The closure period would last for 10 years, during which the peak electric power demand would be much less than that during operations.

The repository demand for electricity would be well within the expected regional capacity for power generation. For 2020, during the operations period, Nevada Power Company projects a summer peak demand of 7,511 megawatts (including a 12-percent reserve margin) (DIRS 173383-Nevada State Office of Energy 2005, p. 23). The maximum 90-megawatt demand that the repository would require would be about 1.2 percent of the projected peak demand in 2020 and less than 10 percent of the planned reserve. While the accuracy and viability of long-term planning for electric power demand is not completely certain, DOE anticipates that regional capacity planning would accommodate the repository demand. Nevada Power Company has demonstrated the ability to meet customer demand in a high-growth environment through effective planning. It expects system sales to grow by more than 30 percent from 2005 to 2020 [from 19 million to more than 25 million megawatt-hours (DIRS 173383-Nevada State Office of Energy 2005, p. 23)]. The maximum annual power use of 790,000 megawatt-hours for the repository would be about 3 percent of the projected 2020 sales volume.

4.1.11.1.4 *Fossil Fuels and other Petroleum Products*

Fossil-fuel use during the construction period would include diesel fuel and gasoline. DOE would use diesel fuel primarily to operate surface construction equipment and equipment to maintain the excavated rock storage pile. Site trucks and automobiles would be the primary users of gasoline. During construction, the estimated maximum annual use of diesel fuel and gasoline would be about 5.5 million and 180,000 liters (1.5 million and 47,000 gallons), respectively. Total fossil fuel use during the construction period would be about 19 million liters (5.0 million gallons). The supply capacity of diesel fuel is about 1.8 billion liters (480 million gallons) per year for the State of Nevada (DIRS 176397-EIA 2005, Table 4). This value is based on distillate fuel sales from 2004. The supply capacity of gasoline is about 4.1 billion liters (1.1 billion gallons) per year for the state (DIRS 182203-EIA 2006). This value is based on gasoline consumption in 2004. About half of the State of Nevada fossil fuel consumption is in the three-county region of Clark, Lincoln, and Nye counties, with the highest consumption in Clark County (DIRS 155970-DOE 2002, p. 4-76). Table 4-29 lists fossil-fuel and oil and lubricant use during the different analytical periods.

During the construction period, maximum yearly repository consumption of diesel fuel would be about 0.3 percent of the 2004 state-wide consumption. Maximum yearly repository consumption of gasoline would be less that 0.005 percent of the 2004 state-wide consumption.

DOE would use fossil fuels during the operations period for construction activities, emplacement activities, onsite vehicles, boilers, and electrical generators. Maximum annual diesel fuel use would be about 20 million liters (5.3 million gallons) and maximum annual gasoline use would be about 850,000 liters (220,000 gallons). Total fossil fuel usage during the operation period would be about 690 million liters (180 million gallons). The maximum annual use of diesel fuel and gasoline would be about 1.1 percent and 0.021 percent, respectively, of the 2004 capacities. The annual use would be highest during full repository operations and would decrease substantially during the monitoring period.

During the closure period, annual fossil-fuel use would be about 27 percent of that for the construction period. During all periods, the projected use of diesel fuel and gasoline would be within the regional supply capacity and would cause little impact.

DOE would use hydraulic oils and lubricants and non-fuel hydrocarbons to support operation of equipment during all periods of the project. Consistent with the analysis in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. 4-77), the quantities of these materials used would be about 22 million liters (5.3 million gallons). DOE would recycle and reuse these materials.

4.1.11.1.5 *Construction Material*

The primary materials for construction of the repository would be concrete, steel, and copper. DOE would use concrete—which consists primarily of cement, fine and coarse aggregate, and water—for liners in the main tunnels and ventilation shafts in the subsurface and for construction of surface facilities. The Department would use aggregate available in the region for the concrete and would purchase cement regionally. Table 4-30 lists the amounts of concrete and cement. During the construction period, the estimated use of concrete would be about 320,000 cubic meters (420,000 cubic yards). The amount of cement required would be about 130,000 metric tons (about 140,000 tons).

The average yearly concrete demand for the construction period would be about 65,000 cubic meters (about 85,000 cubic yards). Annual production of concrete in Nevada equals approximately 6.7 million cubic meters (8.8 million cubic yards) per year (DIRS 173400-NRMCA 2005, p. 2). The annual quantity of concrete required during the construction period represents less than 1 percent of concrete use in Nevada in 2004. Cement would be purchased through regional markets and shipped to the site. Regional suppliers of cement have demonstrated the ability to keep pace with the annual production of concrete in Nevada. DOE expects little or no impact from increased demand for concrete and cement in the region.

For the Proposed Action, DOE would need as much as 280,000 metric tons (310,000 tons) of carbon steel for uses that would include rebar, piping, vent ducts, and track and about 670 metric tons (740 tons) of copper for uses that would include electrical cables. The requirements for carbon steel and copper were not categorized by analytical period in Table 4-30 because total use would be very small relative to annual domestic production. The total usage of carbon steel at the repository would be less than 0.3 percent of the annual domestic production capability of about 100 million metric tons (about 110 million tons). The total usage of copper at the repository would be less than 0.07 percent of the annual domestic mine production. Although worldwide demand for steel is increasing due to economic growth overseas (primarily in China), the markets for steel and copper are worldwide in scope. DOE anticipates little or no impact from increased demand for steel and copper in the region.

4.1.11.1.6 *Site Services*

DOE would rely on the existing support infrastructure during an emergency at the proposed repository (Chapter 3, Section 3.1.11.3) until it completed new onsite facilities during the construction period. Once completed, the new facilities would provide onsite services.

Table 4-30. Construction material use for the Proposed Action.

Analytical period	Use (years)
Construction	5
Operations	up to 50
Monitoring	50
Closure (overlaps last 10 years of Monitoring)	10
Total	up to 105
Concrete	(1,000 cubic meters)
Construction[a]	320
Operations[a]	170
Monitoring[b]	0
Closure[b]	3
Total	490
Cement	(1,000 metric tons)
Construction[a]	130
Operations[a]	65
Monitoring[b]	0
Closure[b]	1.2
Total	190
Carbon steel (1,000 metric tons)[c]	280
Copper (1,000 metric tons)[c]	0.67

Notes: Conversions factors are on the inside back cover of this Repository SEIS. Titanium requirements from the manufacture of drip shields are discussed in Section 4.1.14.

a. Source: DIRS 182713-Morton 2007, all.

b. Source: DIRS 155970-DOE 2002, p. 4-74.

c. Source: DIRS 182197-Morton 2007, all.

The primary onsite response would occur through the multifunctional Fire, Rescue and Medical Facility, which would provide space for fire protection and firefighting services, underground rescue services, emergency and occupational medical services, and radiation protection. The facility would have the capability to provide complete response to most onsite emergencies. A helicopter pad would enable emergency medical evacuation. DOE would coordinate the operation of this facility with facilities in Nye County and at the Nevada Test Site to increase response capability, if necessary. Nye County developed *Nye County Public Safety Report* to recommend that Nye County and DOE integrate public safety services for the repository site and the area just beyond the repository boundary in order to mitigate potential repository impacts to public safety services. The report is summarized and incorporated by reference (DIRS 182710-NWRPO 2007, all).

As stated in the Yucca Mountain FEIS, a site security and safeguards system would include surveillance and safeguards functions to protect the repository from unauthorized intrusion and sabotage (DIRS 155970-DOE 2002, p. 4-78). The system would include site security barriers, gates, and badging and automated surveillance systems operated by trained security officers. Support would be available from the Nevada Test Site security force and the Nye County Sheriff’s Department, if necessary.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities would be able to respond to and mitigate most onsite incidents, which would include underground incidents, without outside support. Therefore, there would be no meaningful impacts to the emergency facilities of surrounding communities or counties.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of waste that DOE could generate as a result of construction, operation and monitoring, and closure activities. The region of influence for waste and hazardous materials consists of on- and offsite areas that include landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of waste it generated under the Proposed Action. The evaluation of waste management impacts used available information to consider the potential for the generation of particular waste types and estimates of the quantities that these activities could generate. The types of waste the Proposed Action would generate would include sanitary and industrial waste, industrial wastewater, low-level radioactive waste, sanitary sewage, hazardous waste, mixed waste, and transuranic waste. DOE based the estimates for the amount of generated waste in this section on construction and operating experience, engineering data, material use estimates, and number of workers. The Department did not generate estimated quantities for mixed and transuranic waste because it anticipates that routine operations would not produce these waste types. However, this section does discuss the management of such waste, if generated.

DOE determined that modifications in the current repository design and operational plans would require a new analysis of repository-generated waste. Therefore, DOE has revised the construction and demolition debris, sanitary sewage, and low-level radioactive waste estimates since the Yucca Mountain FEIS to reflect the modified design and operational plan changes. These changes have resulted in the proposed construction of more but smaller facilities and slight changes in the estimated number of workers for the project. DOE has also revised the low-level radioactive waste estimates to reflect the implementation of the use of TAD canisters. The revised waste estimates were extrapolated from a variety of sources, including the Yucca Mountain FEIS to calculate total waste over the duration of the project. The industrial wastewater and sanitary and industrial waste estimates have not changed because the operational aspects DOE used to generate these estimates for the FEIS are essentially the same. Therefore, the estimates for these waste types are incorporated by reference from the Yucca Mountain FEIS.

This section analyzes impacts from the disposal of repository-generated waste against current disposal waste capacities for offsite and regional waste facilities.

4.1.12.1 Waste and Hazardous Materials Impacts from Construction, Operation and Monitoring, and Closure

Table 4-31 lists the waste and hazardous materials that DOE could generate during the construction, operation, monitoring, and closure periods. The estimates reflect the current repository design and operations aspects that will be in the license application DOE submits to NRC. The construction and

Table 4-31. Total waste quantities (cubic meters) expected to be generated.

Waste type	Total amount
Construction and demolition debris[a]	476,000
Industrial wastewater (million)[b]	1.2
Sanitary sewage (million)	2.0
Sanitary and industrial waste[b,c]	100,000
Hazardous waste[b]	8,900
Low-level radioactive waste[d]	74,000

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Estimate based on materials used.

b. Value remains unchanged from the Yucca Mountain FEIS.

c. Does not include construction and demolition debris.

d. Estimate includes liquid low-level waste and emptied dual-purpose canisters managed as low-level waste.

demolition debris estimates include the dismantling of the temporary structures at the North Portal and the existing Sample Management Facility at the Field Operations Center.

DOE would use one or more of the following to manage construction and demolition debris: disposal at existing landfills at the Nevada Test Site, nearby municipal landfills, or a State-permitted landfill on the Yucca Mountain Site. In addition to the landfills at the Nevada Test Site, there are 23 currently operating municipal solid waste landfills, which include four industrial landfills, in Nevada (DIRS 182603-NDEP 2007, all).

DOE would use four onsite evaporation ponds or a wastewater treatment facility to manage industrial wastewater. Industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal operations area; wastewater from the subsurface would flow to evaporation ponds at the South Portal development area and the North Construction Portal; and wastewater from oil-water separators and super-chlorinated water from maintenance of the drinking water system would flow to evaporations ponds at the Central Operations Area. The evaporation ponds would be lined and any residual sludge would be tested, treated, and disposed of as appropriate, depending on the results of the testing. Section 4.1.3 discusses the evaporation ponds. A wastewater treatment facility is not an element of the current design; if DOE did incorporate this facility, it could use it to treat specifically identified industrial wastewater streams and sanitary sewage. The discharges would be permitted and the associated sludge would be tested, treated, and disposed of as appropriate, depending on the results of the testing. Appendix A discusses the benefits and potential environmental impacts of a wastewater treatment facility.

DOE would use septic systems or possibly a wastewater treatment facility to manage sanitary sewage. Sludge from the septic systems would be tested, treated, and disposed of as appropriate, depending on the results of the testing.

DOE would manage sanitary and industrial waste in the same manner it would manage construction and demolition debris.

DOE would manage hazardous waste by shipment off the site for treatment and disposal. Hazardous waste would be primarily from laboratories, health clinics, and vehicle maintenance shops; examples include solvents, fuels, paints, corrosives, and cleansers. DOE would treat, store, and dispose of waste from these substances appropriately in accordance with federal and state regulations. The Department would not dispose of hazardous waste on the site. It would contract with permitted hazardous wastes transporters to ensure the safe transport of all hazardous wastes from its facilities to a permitted offsite hazardous waste facility for treatment or disposal. The transportation of hazardous materials would be in accordance with federal and state regulations. The U.S. Department of Transportation Office of Hazardous Materials Safety prescribes the regulations for the safe transportation of hazardous materials (40 CFR Part 49).

WASTE TYPES

Industrial waste: Solid waste that is neither hazardous nor radioactive such as construction and demolition debris, rubber, and miscellaneous plastic products. Examples of construction and demolition debris include soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water for dust suppression, rinse water from concrete production and transport, and process water from building heating, ventilation, and air conditioning systems.

Sanitary sewage: Domestic wastewater from sinks, showers, kitchens, floor drains, restrooms, change rooms, and food preparation and storage areas.

Sanitary waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. (State of Nevada waste regulations define this waste stream as *household waste.*)

Hazardous waste: Waste designated as hazardous by EPA or State of Nevada regulations. Hazardous waste, defined under the *Resource Conservation and Recovery Act*, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special EPA lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include personal protective clothing, air filters, solids from the liquid low-level waste treatment process, radiological control and survey waste, and used canisters (dual-purpose).

Transuranic waste: Waste materials (excluding high-level radioactive waste and certain other waste types) contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and that occur in concentrations greater than 100 nanocuries per gram. Transuranic waste results primarily from treatment and fabrication of plutonium and from research activities at DOE defense installations.

Mixed waste: Waste that exhibits the characteristics of both hazardous and low-level radioactive wastes.

DOE would control and dispose of site-generated low-level radioactive waste in a DOE low-level waste disposal site, a site in an *Agreement State*, or an NRC-licensed site. Low-level radioactive waste would be in the form of solids and liquids from operations such as cask, facility, and equipment decontamination with wipes and chemicals; pool system skimming and filtration operations; used dual-purpose canisters; tooling and clothing; facility heating, ventilation, and air conditioning filtration; chemical sumps; and carrier and transporter washings (DIRS 104508-CRWMS M&O 1999, p. 53). Activities during the operations, monitoring, and closure periods would generate about 74,000 cubic meters (2.6 million cubic feet) of low-level waste. Dual-purpose canisters would make up about 9,800 cubic meters (340,000 cubic feet) of low-level waste.

DOE would separate liquid low-level waste into nonrecyclable and recyclable liquid waste. It would process recyclable liquid wastes for reuse through evaporation, condensation, and ion exchange components (DIRS 104508-CRWMS M&O 1999, p. 54). This analysis assumed that the Department would solidify nonrecyclable liquid low-level radioactive waste before offsite shipment. Solidified liquid low-level waste would include approximately 25,000 cubic meters (880,000 cubic feet) of low-level waste (also included in the 74,000 cubic meter total). DOE does not anticipate the generation of mixed or transuranic waste during routine operations, but if unusual activities generated such waste, it would be minimal (DIRS 182319-Morton 2007, all) and DOE would dispose of the waste at an offsite permitted facility.

4.1.12.2 Overall Impacts to Waste Management

Impacts that would be associated with construction and demolition debris and sanitary and industrial wastes would be small because of the number and capacity of offsite solid waste landfills. DOE could build onsite solid waste facilities to accommodate the nonhazardous waste that repository activities generated. In addition, the Department would implement best management practices to reduce waste generation and to avoid or minimize the amount of waste disposed of at Nevada Test Site or regional solid waste facilities. Because DOE would minimize waste as much as possible, the additional waste disposed of at the Nevada Test Site or regional facilities would be small, and these facilities have enough capacity to accommodate such waste.

The regional capacity for treatment and disposal of hazardous waste is greater than the quantity that DOE would generate. The estimated disposal capacity for hazardous wastes in western states is about 50 times the demand for landfills and 7 times the demand for incineration until at least 2013 (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Based on this information, impacts to regional hazardous waste facilities from waste generated from repository activities would be small.

Impacts to licensed disposal facilities from low-level radioactive waste would be small because the amount of such waste would be small. Repository-related activities would generate approximately 638 cubic meters (22,500 cubic feet) of low-level waste annually over the life of the project. For comparison, this only accounts for about 0.5 percent of the low-level waste disposed of in 2005 at commercial low-level waste facilities nationwide (DIRS 182320-NRC 2007).

4.1.13 ENVIRONMENTAL JUSTICE

This section describes the DOE analysis of environmental justice (the potential for impacts to be disproportionately high and adverse to minority or low-income populations). The region of influence for environmental justice varies with resource area and corresponds to the region of influence for each resource area. Since completion of the Yucca Mountain FEIS, the NRC has issued *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (69 FR 52040). This policy defined the identification of low-income and minority communities as the affected area's percentage of minority or low-income population that significantly exceeds that of the state or county. NRC staff guidance defines "significantly" as 20 percentage points. For this Repository SEIS, DOE has chosen to follow the NRC guidance. In addition, the analysis used 2000 Census data available since the Yucca Mountain FEIS to identify low-income population blocks.

4.1.13.1 Impact Assessment Methodology

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, and the associated implementing guidance establish the framework for identification of impacts to low-income and minority populations. The Executive Order directs federal agencies to identify and consider disproportionately high and adverse human health, social, economic, or environmental effects of their actions on minority and low-income communities and American Indian tribes and provide opportunities for community input to the process, which includes input on potential effects and mitigation measures.

DOE performs environmental justice analyses to identify if any high and adverse impacts would fall disproportionately on minority or low-income populations in accordance with guidance from the Council on Environmental Quality. The potential for environmental justice concerns exists if the following occur (DIRS 177702-CEQ 1997, pp. 26 and 27):

- "Disproportionately high and adverse human health effects: When determining whether human health effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable:

- Whether the health effects, which may be measured in risks and rates, are significant (as employed by NEPA), or above generally accepted norms. Adverse health effects may include bodily impairment, infirmity, illness, or death; and

- Whether the risk or rate of hazard exposure by a minority population, low-income population, or Indian tribe to an environmental hazard is significant (as employed by NEPA) and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group; and

- Whether health effects occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards

- Disproportionately high and adverse environmental effects: When determining whether environmental effects are disproportionately high and adverse agencies are to consider the following three factors to the extent practicable:

- Whether there is or will be an impact on the natural or physical environment that significantly (as employed by NEPA) and adversely affects a minority population, low-income population, or Indian tribe. Such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or Indian tribes when those impacts are interrelated to impacts on the natural or physical environment; and

- Whether environmental effects are significant (as employed by NEPA) and are or may be having an adverse impact on minority population, low-income populations, or Indian tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group; and

- Whether the environmental effects occur or would occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards."

The DOE analysis of environmental justice for this Repository SEIS considered the results of analyses of potential impacts to the different resource areas that focused on consequences to resources that could affect human health or the environment for the general population. In addition, the Department determined if unique exposure pathways, sensitivities, or cultural practices would result in different impacts on minority or low-income populations. If either assessment identified potential impacts, the environmental justice analysis then compared the impacts on minority and low-income populations to those on the general population. In other words, if significant impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, disproportionately high and adverse impacts would be unlikely.

The Repository SEIS definition of a minority population is in accordance with the Bureau of the Census racial and ethnic categories. The "Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions" (69 FR 52040; August 24, 2004) states:

> "…a minority or low-income community is identified by comparing the percentage of the minority or low-income population in the impacted area to the percentage of the minority or low-income population in the County and the State. If the percentage in the impacted area significantly exceeds that of the State or the County percentage for either the minority or low-income population then [environmental justice] will be considered in greater detail. "Significantly" is defined by staff guidance to be 20 percentage points. Alternatively, if either the minority or low-income population percentage in the impacted area exceeds 50 percent [environmental justice] matters are considered in greater detail."

Clark and Nye counties had a low-income population of 11 percent in the 2000 Census. Inyo County had a low-income population of 14 percent. Twenty census block groups are within the 80-kilometer (50-mile)-radius circle around Yucca Mountain. No census block group exceeded the 20 percentage-point poverty level and, therefore, no low-income population significantly exceeds that of the state or county. Analysis of block data demonstrated several blocks where the minority population equaled or exceeded 50 percent in all three counties (Chapter 3, Figure 3-19).

Regions of influence, and therefore potentially affected areas, vary with each resource area. If there would be no significant impacts in a resource area's region of influence, or if identified significant impacts would not fall disproportionately on low-income or minority populations, there would be no environmental justice impacts. DOE has identified land use, air quality, cultural resources, socioeconomics, and public health and safety as resources that could be of particular interest to minority or low-income populations. The following sections summarize the impacts to those resource areas.

4.1.13.2 Construction, Operation and Monitoring, and Closure

4.1.13.2.1 *Land Use*

Direct land use impacts from the Proposed Action would be small due to the existing and future restriction of site access for most affected areas (Section 4.1.1). There are no communities with high percentages of minority populations in the region of influence for land use.

4.1.13.2.2 *Air Quality*

Impacts to air quality from the Proposed Action would be small (Section 4.1.2). Further, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust.

4.1.13.2.3 *Cultural Resources*

DOE has implemented a worker education program on the protection of archeological sites and artifacts to limit direct and indirect impacts to them. Before construction began, DOE would avoid archaeological resources or mitigate its actions, so any direct adverse impacts associated with construction and operation of the facilities would be small. In addition, the Department would conduct such activities in a manner that would preclude improper disclosure of, or adverse impacts on, sensitive cultural sites or resources covered by applicable laws and regulations (Section 4.1.5).

4.1.13.2.4 *Socioeconomics*

Socioeconomic impacts from repository construction and operation would be small. Regional employment would increase an estimated 0.1 percent above baseline levels. Changes to the baseline regional population would be no greater than 0.06 percent. Potential impacts to the Gross Regional Product, real disposable personal income, and expenditures by state and local governments would be small. While several communities have minority populations greater than 50 percent, there would be no disproportionately high socioeconomic impacts on those communities (Section 4.1.6).

4.1.13.2.5 *Public Health and Safety*

The analysis determined that the impacts that could occur to public health and safety would be small throughout the Proposed Action (Section 4.1.7). There would be no nonradiological adverse health effects for the public within the 80-kilometer (50-mile) radius around the repository. The elapsed time between initiation of repository construction and closure would be 105 years. No subsection of the population, including minority populations, would receive disproportionate impacts.

4.1.13.3 Environmental Justice Impact Analysis Results

As in the Yucca Mountain FEIS, this Repository SEIS analysis used information from Sections 4.1.1 to 4.1.12. DOE does not identify any high and adverse potential impacts to populations. Further, DOE has not identified subsections of the population, including minority or low-income populations, that would receive disproportionate impacts, and it has identified no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income populations to disproportionately high and adverse impacts. Therefore, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 An American Indian Perspective

In the Yucca Mountain FEIS, DOE acknowledged that people from American Indian tribes have used the proposed repository area as well as nearby lands, and that lands around the site contain cultural, animal, and plant resources important to those tribes. The tribes presented their views in *American Indian*

Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement, which states (DIRS 102043-AIWS 1998, p.2-9):

> "…we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence."

DOE acknowledges that disposal of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain would conflict with the viewpoints in the perspectives document (DIRS 102043-AIWS 1998, all). If DOE received authorization to construct the repository, it would engage in regular consultations with representatives of tribes in the region to identify measures to protect cultural resources and thereby address some of the concerns the tribes have expressed.

4.1.14 IMPACTS FROM MANUFACTURING REPOSITORY COMPONENTS

This section discusses the potential environmental impacts from the manufacture of components that DOE would require to move and dispose of spent nuclear fuel and high-level radioactive waste at a geologic repository at Yucca Mountain. Repository components would include canisters, waste packages, emplacement pallets, drip shields, aging overpacks, shielded transfer casks, and shipping casks. Other repository-related items (for example, cranes and other heavy equipment, miscellaneous mechanical components, electrical components, structural materials) are considered standard commercially available components that DOE could buy from several vendors. As a result, there would be no offsite manufacturing environmental impacts specifically attributed to these other types of repository equipment and components and they are not included in this evaluation. This section updates information in the Yucca Mountain FEIS and summarizes and incorporates by reference Section 4.1.15 of the FEIS (DIRS 155970-DOE 2002, pp. 4-91 to 4-105). The primary updates or modifications since the FEIS evaluation are the addition of TAD canisters to the list of repository components, slight changes in the numbers of other components, updated information on the environmental and socioeconomic settings of the reference manufacturing facilities, and expansion of the analysis of air quality impacts to include $PM_{2.5}$.

Section 4.1.14.1 provides an overview of the analysis basis. Section 4.1.14.2 discusses the components that offsite manufacturers would fabricate and the manufacturing schedule. Section 4.1.14.3 describes the components in detail. Section 4.1.14.4 discusses environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.14.5 describes environmental impacts on air quality, health and safety, socioeconomics, waste generation, and environmental justice; in addition, this section contains an evaluation of materials use that addresses the potential for impacts to materials markets and supplies.

4.1.14.1 Overview

This analysis and the corresponding analysis in the Yucca Mountain FEIS used the overall approach, analytical methods and, in some cases, baseline data from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (DIRS 101941-USN 1996, all). The evaluation addressed ways in which the manufacture of repository components could affect environmental attributes and resources at a representative manufacturing site. DOE did not perform a site-specific evaluation because more than one manufacturer probably would be necessary to meet the production schedule and, until competitive bidding was complete, the Department would not know the locations of specific manufacturing facilities.

The analysis used a representative manufacturing site based on five existing facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel with the use of NRC-certified designs. The facilities, which are the same as those the Navy used in its EIS (DIRS 101941-USN 1996, p. 4-17), are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee. Although the analysis used the existing facilities from the earlier evaluation, it used updated information to characterize the environmental settings for the facility locations.

The analysis assumed that the manufacturing facilities and processes at these locations are similar to the facilities and processes that would be necessary to produce the repository components. Although the five reference facilities might not fabricate components from titanium (which DOE would use in the drip shields), the fabrication processes of rolling plate, forming, and welding that would be necessary to produce a drip shield would be similar to the processes for casks and canisters from other structural material. The analysis also assumed that manufacture of all components would occur at one representative site. Although this is unlikely, it is conservative because potential impacts would be concentrated and higher than if they were in several locations.

4.1.14.2 Components and Product Schedule

Table 4-32 lists the components and the quantities of components DOE included in the analysis; the table includes TAD canisters (Section 4.1.14.3), which the Yucca Mountain FEIS did not address. The table includes all repository components for naval spent nuclear fuel that the Department would emplace at Yucca Mountain, but does not include the shipping casks, which the Navy would manufacture as owner and manager of that spent fuel. The Navy EIS (DIRS 101941-USN, 1996, all) discusses these casks and the potential environmental impacts of their production.

Table 4-32. Quantities of offsite-manufactured components for the Yucca Mountain Repository.

Component	Description	Number to be manufactured[a]
Rail shipping casks or overpacks	Storage and shipment of SNF and HLW	79
Truck shipping casks	Storage and shipment of uncanistered fuel	30
Waste packages	Outside container for SNF and HLW emplacement in the repository	11,200
TAD canisters	Transportation, aging and disposal canisters for commercial SNF	7,400[b]
Emplacement pallets	Support for emplaced waste packages	11,200[c]
Drip shields	Titanium covers for waste packages	11,500
Aging overpacks	Metal and concrete storage vaults for aging[d]	2,500
Shielded transfer casks	Casks for transfer of canisters between and in site facilities	6–10

a. The number of components is an approximation, but is based on the best available estimates.
b. Total number of empty TAD canisters includes those shipped to generator sites and to the repository.
c. The number of emplacement pallets includes about 10,030 of the standard length and 1,150 of the short length.
d. Only the metal components of the aging overpacks would be manufactured offsite.
HLW = High-level radioactive waste. TAD = Transportation, aging, and disposal (canister).
SNF = Spent nuclear fuel.

The analysis assumed the manufacture of all the components except drip shields would occur over 24 years to support the maximum rate of emplacement. The operations period would last as long as 50 years (Chapter 2, Table 2-1), so component manufacturing likely would be on a longer schedule and still keep up with demand. However, the assumed faster pace is conservative because it concentrates estimated impacts into a shorter timeframe. Manufacturing activity would begin 2 years before repository operations started, would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period. Because DOE would not need the drip shields until the closure period, the analysis assumed the period for manufacture and delivery of them would be 10 years and would not coincide in any year with the manufacture of the other components.

4.1.14.3 Components

4.1.14.3.1 *Waste Packages*

The waste package (which the Yucca Mountain FEIS called the disposal container) would be the final outside container DOE would use to package the spent nuclear fuel and high-level radioactive waste for emplacement in the repository. The basic design remains as it was in the FEIS; that is, it would be a cylindrical vessel with an outer layer of corrosion-resistant nickel-based alloy [Alloy 22 (UNS N06022)] and an inner liner of Stainless Steel Type 316. Both the inner liner and the outer layer would have lids of the corresponding materials at both ends. The bottom lids would be welded to the cylindrical body at the fabrication shop and the top inner and outer lids would be welded in place at the repository after insertion of the canister (or canisters) with spent fuel or high-level radioactive waste. DOE has eliminated a third lid for the closure end from the design in the FEIS.

The Yucca Mountain FEIS described the proposed use of about 10 different waste package configurations to accommodate the different types of spent nuclear fuel and high-level radioactive waste. Although the basic waste package design would be the same for the various waste forms, DOE has reduced the number of configurations to six by standardizing the waste package for commercial spent nuclear fuel. The Department accomplished this standardization through the introduction of a new TAD canister, which is described below. In addition to waste package changes to accommodate the TAD canister and to eliminate the third closure lid, other changes in proposed waste package configurations resulted in changes to the size and mass of material. A notable change in several of the configurations was a slight elongation of the package to allow a thick inner lid that also serves as a shield plug. The discussions in this section incorporate these and other minor changes. The six waste package configurations range in length from 3.7 to 5.9 meters (12 to 19 feet), with outside diameters of 1.8 to 2.1 meters (6 to 7 feet). The mass of empty waste packages would range from 22 to 34 metric tons (24 to 38 tons).

4.1.14.3.2 *Transportation, Aging, and Disposal Canisters*

Management of commercial spent nuclear fuel would be more standardized by the use of TAD canisters, which the Yucca Mountain FEIS did not consider. TAD canisters are cylindrical containers, approximately 5.4 meters (18 feet) long with an outer diameter of about 1.7 meters (5.5 feet). The shell of the canister would be stainless steel and the inner basket would be configured differently for different types of spent nuclear fuel. The inner basket would include borated stainless steel to act as a neutron absorber. The mass of an empty TAD canister would range from about 29 to 31 metric tons (32 to 34 tons) depending on the internal basket configuration. Under the Proposed Action, about 90 percent of the commercial spent nuclear fuel would travel to the repository in TAD canisters; commercial sites would load and seal these canisters. The remaining 10 percent of the commercial spent fuel would be transported in other types of canisters, or as uncanistered fuel (in casks), and DOE would repackage it in TAD canisters at the repository site. This analysis includes TAD canisters as repository components because they are an element of the repository design and the commercial nuclear facilities would have to use them as appropriate.

4.1.14.3.3 *Casks for Rail and Truck Shipments*

DOE would mainly use rail casks to ship spent nuclear fuel and high-level radioactive waste to the proposed repository, but would also use some truck casks. The Department would tailor the design of a specific cask to the type of material it would contain. As in the Yucca Mountain FEIS, a typical rail or truck cask or overpack would consist of inner and outer cylinders of stainless or carbon steel with a depleted uranium or lead liner between the cylinders. The vessel bottom would have a similar layered construction of plates welded to the cylinder ends. A cask would probably have an inner structure to keep the contents secure, and an overpack would have no internal structures because it would be sized for a specific disposable canister. A polypropylene sheath would be around the outside of the cylinder for neutron shielding. After the spent nuclear fuel or high-level radioactive waste was placed inside the cask or overpack, a cover with lead or depleted uranium shielding would be bolted to the top of the cylindrical vessel. Large removable impact limiters of aluminum honeycomb or other crushable material would be placed over the ends of the casks or overpacks for added protection during shipment. Typical casks and overpacks would range from 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. Empty truck casks could weigh from 21 to 22 metric tons (about 23 to 24 tons) and empty rail casks would typically weigh from 59 to 91 metric tons (65 to 100 tons).

4.1.14.3.4 *Emplacement Pallets*

The emplacement pallets would support the waste packages inside the repository and would allow close spacing [to within 10 centimeters (4 inches)] of the end-to-end waste packages. The design of these components is essentially unchanged from that in the Yucca Mountain FEIS. The pallets would have V-shaped supports at either end on which the waste package would rest, and the end pieces of the pallets would connect with structural tube members. The pallet assemblies would be a combination of Alloy 22 components (primarily plates) and stainless-steel tubes. Surfaces that would contact the waste package would be Alloy 22. The shorter pallet would be 2.5 meters (8.2 feet) long and have a mass of 1.7 metric tons (1.9 tons) (DIRS 181901-Morton 2007, all); DOE would use them only for the shortest waste package for DOE spent nuclear fuel and high-level radioactive waste. The longer pallet would be 4.1 meters (14 feet) long and have a mass of 2 metric tons (2.2 tons) (DIRS 181901-Morton 2007, all); DOE would use this pallet for all other waste packages.

4.1.14.3.5 *Drip Shields*

The drip shields would be rigid structures above the waste packages that would divert water around them and provide protection from rockfalls. It would consist of Titanium Grade 7 surface plates, Titanium Grade 29 structural members, and Alloy 22 for the base. DOE would install the continuous drip shield in sections, with one that overlapped and interlocked with the opposite end of the next section. Each section would be 5.8 meters (19 feet) long by 2.5 meters (8 feet) wide by 2.9 meters (9.5 feet) high with a mass of 4.9 metric tons (5.4 tons) (DIRS 181901-Morton 2007, all).

4.1.14.3.6 *Aging Overpacks*

Aging overpacks (which the Yucca Mountain FEIS called dry storage casks) would hold TAD canisters of commercial spent nuclear fuel for aging to meet waste package thermal limits. Vertical and horizontal aging overpacks would consist of an inner liner of about 5-centimeter (2-inch)-thick carbon steel surrounded by a roughly 76-centimeter (30-inch)-thick layer of reinforced concrete, which might, depending on the vendor, have an exterior carbon-steel shell of 2.5- to 5-centimeter (1- to 2-inch) thickness (DIRS 181901-Morton 2007, all). This evaluation considered as components only the carbon-steel shells that would be manufactured off the site. It assumed the carbon-steel elements of the aging overpack would weigh about 43 metric tons (47 tons).

4.1.14.3.7 *Shielded Transfer Casks*

DOE would use shielded transfer casks to transfer TAD canisters and other canisters between and in the site facilities. These components would essentially be transportation casks without impact limiters. The analysis took estimates of their size and materials of manufacture directly from information on casks that DOE would use for rail shipment, with a slight reduction to account for the fact that they would have no impact limiters.

4.1.14.4 Existing Environmental Settings at Manufacturing Facilities

DOE based the assessment of potential impacts from the manufacture of repository components, as it did in the Yucca Mountain FEIS, on the premise that existing facilities would meet the manufacturing requirements. Therefore, there would be no new or expansion construction. As a result, there would be no change in land use, and cultural, aesthetic, and ecologic resources would remain unaffected. Minor increases in noise, traffic, or utilities would be likely, but would not result in impacts on the local environment. Water consumption and wastewater discharges would be typical of a heavy manufacturing facility, and the proposed manufacturing of repository components would probably result in minor changes to existing rates. In the case of wastewater discharges, nothing unique would be likely as a result of the Proposed Action that could cause difficulty in compliance with applicable local, state, and federal regulatory limits. The following sections contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.14.5 describes potential environmental impacts for a representative site.

DOE recognizes that the basic assumption of no new or expansion construction might not be the eventual situation because the number of components to manufacture is large. However, at the current stage of the Proposed Action, it would be highly speculative to assume construction would be necessary. In addition, there would be too much uncertainty to attempt to address specific facility impacts that could be associated with construction.

4.1.14.4.1 *Air Quality*

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas of the existing reference facilities. As the Yucca Mountain FEIS described, most of the typical container and cask manufacturing facilities are in nonattainment areas for ozone; that is, locations where ambient air quality standards are not being met and, as a result, are subject to more stringent regulations. Since the completion of the FEIS, the EPA has established attainment and nonattainment designations for ambient air concentrations of $PM_{2.5}$. As of May 30, 2007, EPA still identified the five counties of the reference manufacturing facilities as being in nonattainment for ozone and four of the five counties as being in nonattainment for $PM_{2.5}$ (DIRS 181914-EPA 2007, all). Each of the counties was in attainment for ambient air quality standards for the other criteria pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead). Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production and, because ozone was the only nonattainment air pollutant at the time, they were the only air pollutants that DOE evaluated in the Yucca Mountain FEIS. DOE has expanded the current evaluation to include $PM_{2.5}$. The five counties released an average of approximately 2,700 metric tons (3,000 tons) of volatile organic compounds, 5,500 metric tons (6,100 tons) of nitrous oxides, and 1,100 metric tons (1,300 tons) of $PM_{2.5}$ to the environment in 1999 (DIRS 181916-EPA 2007, all; DIRS 181917-EPA, all; DIRS 181918-EPA, all; DIRS 181919-EPA, all; DIRS 181920-EPA, all).

4.1.14.4.2 *Health and Safety*

As in the Yucca Mountain FEIS, DOE based data on the number of accidents and fatalities in relation to cask and canister fabrication at the representative manufacturing location on national incident rates for the relevant sector of the economy. The FEIS used incident rates from 1992 of 3 fatalities per 100,000 workers and 6.3 incidents of reportable occupational illness or injury per 100 full-time workers. For this evaluation, DOE has updated these rates with more recent data from the U.S. Department of Labor Bureau of Labor Statistics. The incident rate for this Repository SEIS evaluation is 3.3 fatalities per 100,000 workers, which is the average of the 2003 to 2005 values for the standard industrial code for boiler, tank, and shipping container manufacturing (DIRS 181921-BLS 2007, all; DIRS 181922-BLS 2007, all; DIRS 181924-BLS, all). The analysis used an incidence rate for reportable occupational illness or injury in the evaluation of 9.2 per 100 full-time workers, which is the average of the 2001 to 2005 values for the same standard industrial code (DIRS 181925-BLS 2007, all; DIRS 181926-BLS 2007, all; 181927-BLS 2007, all; DIRS 181928-BLS 2007, all; DIRS 181929-BLS 2007, all).

As noted in the Yucca Mountain FEIS, facilities with extensive experience in similar types of work; well-established procedures; appropriate equipment for fabrication of large, heavy metal components; and experienced and trained personnel would perform the manufacture of repository components. As a result, DOE anticipates that injury and illness rates would be equal to or lower than industry rates.

4.1.14.4.3 *Socioeconomics*

The five reference manufacturing facilities are in U.S. Bureau of the Census Metropolitan Statistical Areas. Where available, this analysis used data for the Statistical Areas to define the affected socioeconomic environment for each facility. This differs slightly from the analysis in the Yucca Mountain FEIS, which used socioeconomic data for the counties of location. The populations of the affected environments for the five facilities ranged from about 410,000 to 780,000 in 2005 (DIRS 181931-Bureau of the Census 2006, all). In 2002, output (the value of sales, shipments, receipts, revenue, or business produced in the five areas) ranged from $21 billion to $50 billion (DIRS 182017-Bureau of the Census 2005, all; DIRS 182018-Bureau of the Census 2005, all; DIRS 182020-Bureau of the Census 2005, all; DIRS 182021-Bureau of the Census 2005, all; DIRS 182022-Bureau of the Census 2005, all; DIRS 182023-Bureau of the Census 2005, all; DIRS 182024-Bureau of the Census 2005, all; DIRS 182026-Bureau of the Census 2005, all; DIRS 182027-Bureau of the Census 2005, all; DIRS 182028-Bureau of the Census 2005, all). The income (wages, salaries, and property income) ranged from $11 billion to $26 billion in 2002, and the labor force ranged from 220,000 to 400,000 in 2004 (DIRS 181932-

Bureau of the Census 2006, all; DIRS 181933-Bureau of the Census 2006, all). Based on averages of this information, DOE estimated the representative manufacturing location would have a population of about 610,000, a labor force of about 320,000, local income of about $19 billion in 2002, and local output of about $35 billion in 2002.

4.1.14.5 Environmental Impacts

As noted above, this evaluation assumed the use of existing manufacturing facilities, so DOE only analyzed environmental impacts to air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.14.5.1 *Air Quality*

As in the Yucca Mountain FEIS, the analysis used the methods from the Navy EIS (DIRS 101941-USN 1996, Section 4.3) to estimate air emissions from manufacturing sites for the production of repository components. However, DOE updated baseline data if available rather than using those in the original methodology. The objective of the evaluation was to estimate emissions for comparison with typical regional or county-wide emissions to determine potential impacts on local air quality.

The evaluation addressed air emissions in relation to the manufacture of repository components that were of most concern to the representative manufacturing location; that is, emissions that could aggravate ambient air conditions already in nonattainment of applicable air quality standards. Based on the reference locations, DOE assumed the representative manufacturing location would be in an area of nonattainment for ozone and $PM_{2.5}$ standards, but in compliance with standards for other criteria pollutants (Section 4.1.14.4). Ozone normally forms in a reaction of precursor chemicals (which includes volatile organic compounds and nitrous oxides) and sunlight, so this evaluation addresses emissions of these precursors as well as of $PM_{2.5}$.

DOE used the emissions from the manufacture of similar components to develop estimates for emissions of volatile organic compounds and nitrous oxides (DIRS 101941-USN 1996, p. 4-6) and normalized, or adjusted, them to the scale of the repository components in relation to the number of work hours for the manufacturing process, as it did in the Yucca Mountain FEIS analysis. The Navy EIS (DIRS 101941-USN 1996, all) did not include emissions of $PM_{2.5}$ in the record of emission from the manufacture of similar components; DOE found no applicable emission rates in normal sources for such data, so it developed an estimated emission rate from available local and national records. EPA maintains a database of air emissions that contains data sortable by geographic area, emissions sources, and standard industrial codes (DIRS 181916-EPA 2007, all; DIRS 181917-EPA, all; DIRS 181918-EPA, all; DIRS 181919-EPA, all; DIRS 181920-EPA, all). County emission records were queried for each reference manufacturing location and for sources that involve the manufacture of metal products. $PM_{2.5}$ emissions tended to vary in proportion to nitrous oxide emissions more consistently than with those of volatile organic compounds. Another query of the same records found that, on a nation-wide basis, the standard industrial code for metal plate fabrication was responsible for emissions of 290 metric tons (315 tons) of $PM_{2.5}$ and 220 metric tons (240 tons) of nitrous oxides in 1999. Based on this information, the evaluation assumed a ratio of 315 to 240 (the original values) to that of nitrous oxide to estimate the $PM_{2.5}$ emissions.

Table 4-33 lists the estimated annual average and estimated total emissions from the manufacture of repository components. Estimated annual average emissions of volatile organic compounds would be

Table 4-33. Air emissions at the representative manufacturing location.

Time period	Measure	Emissions (metric tons) and de minimis values (percent)		
		Volatile organic compounds	Nitrous oxides	$PM_{2.5}$
24-year period[a]	Annual average	2.6	3.3	4.4
	24-year total	62	80	110
	Percent of de minimis[b]	28%	37%	4.8%
10-year period[c]	Annual average	0.65	0.84	1.1
	10-year total	6.5	8.4	11
	Percent of de minimis[b]	7.1%	9.2%	1.2%

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. The 24-year manufacturing period would be for all components except drip shields and would begin 2 years before emplacement.

b. De minimis level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons (10 tons) per year of volatile organic compounds or nitrogen compounds, and for any nonattainment for $PM_{2.5}$ it is 91 metric tons (100 tons) per year of $PM_{2.5}$.

The 10-year manufacturing period would be for drip shields only and would occur at repository closure.

$PM_{2.5}$ = Particulate matter with an aerodynamic diameter of 2.5 micrometers or less.

2.6 metric tons (2.8 tons) a year for the 24-year period and 0.65 metric ton (0.71 ton) per year for the 10-year drip shield manufacturing period. Nitrous oxide emissions would be 3.3 metric tons (3.7 tons) a year for the 24-year period and 0.84 metric ton (0.92 ton) a year for the 10-year drip shield manufacturing period. $PM_{2.5}$ emissions would be 4.4 metric tons (4.8 tons) a year for the 24-year period and 1.1 metric tons (1.2 tons) a year for the 10-year drip shield manufacturing period. Annual average emissions from component manufacturing would be 0.09 percent, or less, of the typical regional emissions of volatile organic compounds of 2,700 metric tons (3,000 tons) per year (Section 4.1.14.4), 0.06 percent, or less, of regional nitrous oxide emissions of 5,500 metric tons (6,100 tons) per year, and 0.4 percent, or less, of regional $PM_{2.5}$ emissions of 1,100 metric tons (1,300 tons) per year. Emissions from the manufacture of repository components would contain relatively small amounts of ozone precursors and $PM_{2.5}$ in comparison to other sources.

If the emissions were from new sources, they would be subject to emission threshold levels (levels below which conformity regulations do not apply) set under 40 CFR 51.853. For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year and for any level of nonattainment for $PM_{2.5}$ the emission threshold level (for $PM_{2.5}$) is 91 metric tons (100 tons) per year. Table 4-33 lists the percentage of volatile organic compounds, nitrous oxides, and $PM_{2.5}$ from the manufacturing of repository components in relation to the applicable emission levels (the analysis assumed extreme nonattainment is the applicable threshold in the case of ozone). It is unlikely that component manufacturing would fall under the conformity regulations because the closest emission to the applicable threshold, or *de minimis*, levels is 37 percent. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each manufacturing facility.

States with nonattainment areas for ozone or $PM_{2.5}$ could place requirements on stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds, nitrous oxides, and $PM_{2.5}$. Options such as additional scrubbers, afterburners, carbon filters, or physical filters would be available to control emissions of these compounds to comply with limitations.

4.1.14.5.2 *Health and Safety*

The analysis used updated data from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate large metal objects similar to the repository components. It computed the expected number of injuries and fatalities by multiplying the number of work years by the injury and fatality rate for the applicable occupation. Table 4-34 lists the expected number of injuries and illnesses and fatalities. Estimated incidents of reportable injury and illness would be approximately 1,700 during the entire manufacturing period, but the probability of a fatality would be less than one.

Table 4-34. Occupational injuries, illness, and fatalities at the representative manufacturing location.[a]

Parameter	Estimated values
Total work years (using 2,000 hours per labor year)	18,500
Injuries and illnesses	1,700
Fatalities	0.61

a. Impacts from 24 years for manufacture of all components except drip shields and 10 years for manufacture of drip shields.

The required number of repository components would not place unusual demands on existing manufacturing facilities, so the action would be unlikely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that include detailed procedures, both of which lead to improved worker safety.

4.1.14.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost and labor data for the components (Table 4-32),
- Total number of components (Table 4-32), and
- Economic data for the environmental setting for each facility to calculate direct and secondary economic impacts of repository component manufacturing on the local economy:
  - The local economy would be directly affected as manufacturing facilities purchased materials, services, and labor for manufacturing.
  - In addition, the local economy would experience secondary effects as industries and households that supplied the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, which would thereby generate additional socioeconomic impacts.

The analysis measured impacts in terms of output (the value of sales, shipments, receipts, revenue or business), income (wages, salaries, and property income), and employment (number of jobs).

In the Yucca Mountain FEIS, the socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products for each of the five states of the reference manufacturing plants. The multipliers of interest were for products, income, and employment (DIRS 155970-DOE 2002, Table 4-48); DOE used them to account for direct and secondary effects on an area's economy. In the FEIS analysis, DOE obtained the state multipliers (DIRS 152803-Bland 1998, all) in accordance with guidelines from the Bureau of Economic Analysis for use of the Regional Input-Output Modeling System, and averaged them to produce composite multipliers for a representative manufacturing location. The composite multipliers were as follows:

- Final demand multiplier for products (dollar value) – 2.2233
- Final demand multiplier for earnings (dollar value) – 0.6308
- Direct effect multiplier for number of jobs – 2.5705

The evaluation of manufacturing for this Repository SEIS included an informal run of the same Regional Input-Output Modeling System that used more recent, national level socioeconomic data as a sensitivity analysis for the economic multipliers used previously. The results indicated that the multipliers DOE used for the Yucca Mountain FEIS evaluation were still reasonable and that a formal modeling effort to update the numbers for each of the reference manufacturing locations would provide little value.

The analysis estimated the direct and secondary impacts of manufacturing activities, but did not include impacts on local jurisdictions such as county and municipal government and school district revenues and expenditures. Because the analysis assumed that manufacturing activities would occur at existing facilities alongside existing product lines, substantial population increases due to workers moving into the vicinity would be unlikely. As a result, impacts to demographics (that is, to characteristics of the population) would be small and meaningful change in local government or school districts would be unlikely. The analysis also did not consider impacts on other areas of socioeconomic concern that population increases would drive, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period of 10 years for drip shields and 24 years for all other components. It compared the impacts to the baseline information from Section 4.1.14.4, with escalation to 2006 dollars. Because the analysis was not site-specific, it made no attempt to forecast local population or economic growth or inflation rates for the reference locations. Table 4-35 lists impacts of component manufacturing on output, income, and employment at the representative manufacturing locations. The table includes a comparison, in terms of percent, of the values for component manufacturing to comparable baseline values for the representative location. As listed in Table 4-35, socioeconomic impacts at the representative manufacturing location would involve relatively minor increases to existing conditions. The largest forecasted increase would be an addition of as much as 4.6 percent to the area's output. Estimated impacts to the area's average income and average employment would be less.

4.1.14.5.4 *Impacts on Materials Use*

The Yucca Mountain FEIS analysis based calculations of the quantities of materials for the manufacture of each repository component, to the extent available, on engineering specifications for each hardware

Table 4-35. Socioeconomic impacts at the representative manufacturing location.

Economic parameter and descriptions of assessment values	24-year period[a]	10-year period[b]
Average annual output		
Baseline output escalated to 2006 dollars (in $ millions)[c]	39,000	39,000
Output associated with manufacture of components (in $ millions)	1,800	890
Percent impact	4.6	2.3
Average annual income		
Baseline income escalated to 2006 dollars (in $ millions)[c]	21,000	21,000
Income associated with manufacture of components (in $ millions)	520	250
Percent impact	2.5	1.2
Average annual employment		
Baseline labor force (persons)[c]	320,000	320,000
Employment associated with manufacture of components (persons)	2,000	500
Percent impact	0.63	0.16

a. The 24-year manufacturing period would be for all components except drip shields and would begin 2 years before emplacement.

b. The 10-year manufacturing period would be for drip shields only and would occur at repository closure.

c. Baseline output, income, and labor force values from Section 4.1.14.4. An escalation factor of 1.12 was applied to the 2002 baseline output and income dollars to obtain the 2006 dollars shown in the table.

component. DOE obtained the information and applicable references from the manufacturers of systems either designed or under licensing review or from conceptual design specifications for technologies still in the planning stages. This Repository SEIS evaluation started with the same information and augmented it with preliminary design drawings of waste packages with minor modifications to the designs in the FEIS and with specifications (DIRS 179349-DOE 2006, all) for the TAD canisters and specific items of support hardware (transportation overpacks and aging overpacks). The analysis combined data on per-unit material quantities for each component with information on the required number of components. In addition, it assessed the impact of component manufacturing on total U.S. production (or availability if not produced in this country) of each relevant input material.

Table 4-36 lists the total quantities of materials that DOE would need for the manufacture of repository components and the average annual requirement for each material. The largest materials requirement by weight would be steel at about 337,000 metric tons (371,000 tons). Table 4-36 also lists the annual U.S. production or import (nickel and titanium) quantities from 2006 (DIRS 182033-USGS 2007, all) for most of the materials. The exception is the quantity for depleted uranium, which is from the 1996 Navy EIS (DIRS 101941-USN 1996, p. 4-10). With the exception of chromium, nickel, and titanium, the requirement for each material would be less than 2 percent of the annual U.S. production. Therefore, the use of aluminum, copper, lead, molybdenum, depleted uranium, or steel would not produce a noteworthy increased demand and would not have a meaningful effect on the supply of these materials.

The estimated annual requirement for chromium as a component in stainless-steel and high-nickel alloy would be about 3.4 percent of the annual U.S. production. Chromium is an important constituent of many types of stainless steel, and about 75 percent of U.S. chromium use is from imports (DIRS 182033-USGS 2007 p. 6). The sum of imported chromium and domestic production in 2006 (Table 4-36) is 480,000 metric tons (529,000 tons). The annual requirement for chromium to manufacture repository components would be only 0.88 percent of that value. Assuming imports remained at current levels, repository use of chromium would not produce a noteworthy increased demand and would not have a meaningful effect on supply.

Table 4-36. Total and annual materials use and comparison to annual production.

Materials	Annual U.S. production or imports[a] (metric tons)	Materials required for repository components: Total (metric tons)	Annual (metric tons)	Percentage of annual production
Aluminum	3,400,000	850	81	0.002
Chromium[b]	125,000	100,000	4,200	3.4
Copper	1,340,000	140	5.9	0.0004
Depleted uranium	14,700	1,500	61	0.41
Lead	1,270,000	1,100	47	0.004
Molybdenum[c]	60,500	27,000	1,100	1.8
Nickel[d,e]	***182,000***	120,000	5,000	2.7
Steel (and iron)[f]	96,400,000	337,000	14,000	0.015
Titanium[e,g]	***25,100***	54,000	5,400	22

Sources: Depleted uranium: DIRS 101941-USN 1996, p. 4-10.
Other materials: DIRS 182033-USGS 2007, year 2006 data, pp. 18, 44, 52, 92, 110, 112, 84, and 176.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Annual values include, as applicable, primary and secondary production.
b. Required chromium estimated as 18 percent of stainless steel and 22 percent of high-nickel alloy.
c. Required molybdenum estimated as 2.5 percent of stainless steel and 14.5 percent of high-nickel alloy.
d. Required nickel estimated as 57.2 percent of high-nickel alloy and 12 percent of stainless steel.
e. Production values for nickel and titanium are import quantities from 2006 (see explanation in text).
f. Required steel estimated as 100 percent of carbon steel and 52 percent of stainless steel. The data source identified steel and iron as a single category, but noted that more than 95 percent of produced iron moves in molten form to steelmaking furnaces at the same site, so the combined quantity is appropriate for comparison. The corresponding materials requirements are for steel.
g. Required titanium estimated as 100 percent of Titanium Grade 7 and 90 percent of Titanium Grade 29.

The estimated annual requirement for nickel as a component in stainless-steel and corrosion-resistant high-nickel alloy would be about 2.7 percent of the annual use, which in this case is all imported material. The materials production data provide no U.S. production values for nickel, but rather lists a W, which indicates the values were withdrawn to avoid disclosure of proprietary data. This indicates U.S. production is limited and values could be easily tied to a specific production company (or companies). The United States imports about 60 percent of the nickel it uses (DIRS 182033-USGS 2007, p. 6). The other 40 percent (not in Table 4-36) is due to a relatively large U.S. market for nickel scrap. In 2006, 107,000 metric tons (118,000 tons) of this scrap were purchased and about 74 percent of the nickel was recovered from it (DIRS 182033-USGS 2007, p. 112). The sum of the imported nickel (Table 4-36) and the recovered nickel is 240,000 metric tons (265,000 tons). The annual requirement for nickel to support the manufacture of repository components would be 2.1 percent of that value. The world mine production for nickel was at an all-time high in 2006, but still barely kept up with demand (DIRS 182033-USGS 2007, p. 112). Although 2.1 percent would be a small portion of the U.S. nickel market, potential impacts on supply would depend on the ability to maintain import levels. Canada is a major world supplier of nickel and the largest U.S. supplier.

The annual requirement for titanium for drip shields would be approximately 5,400 metric tons (5,950 tons) and, at 22 percent, the most critical quantity in terms of its available supply in 2006. As with nickel, the titanium production in Table 4-36 is all in the form of imported material. Similar to nickel, the materials production data provide no U.S. production values for titanium, but rather lists a W to indicate the companies withdrew the values to avoid disclosure of proprietary data, which in turn indicates limited U.S. production. The data indicate that the United States imports about 72 percent of the titanium it uses (DIRS 182033-USGS 2007 p. 6), so the total quantity of titanium used in the United States in 2006 was about 34,900 metric tons (38,500 tons) and the annual amount required for production of repository components would decrease to 15 percent of the larger quantity. Because of increasing demand for titanium in the world market, producers are adding capacity. In the United States, one idle production facility restarted in 2006, another existing facility should increase production significantly in 2007, and a new facility should start production in 2008. Between these three facilities, annual production is estimated to be about 31,000 metric tons (34,000 tons) by the end of 2008 in comparison to a 2006 U.S. capacity of about 12,300 metric tons (13,600 tons) per year (DIRS 182033-USGS 2007, p. 177). If the projected 2008 capacity represented all U.S. production and imports continued at current levels, titanium use in the United States would increase to about 56,000 metric tons (62,000 tons) per year and the annual amount for production of repository components would decrease to 9.6 percent. In addition, DOE would not need the drip shields until the repository closure period, so there would be adequate time (up to 90 years) to complete production of titanium or import additional material in advance of the need. Taking advantage of this schedule, the assumed 10-year production rate for the annual titanium requirement could be less by almost a factor of 10, and potential impacts on markets would be small.

4.1.14.5.5 *Impacts of Waste Generation*

The primary materials for the manufacture of repository components would be stainless steel, carbon steel, high-nickel alloy, aluminum, copper, and titanium along with either depleted uranium or lead for shielding. The manufacture of shielding would generate a hazardous waste or low-level radioactive waste, depending on the material. DOE has identified other types and quantities of waste the manufacturing activities would generate. The analysis based estimates of annual quantities of waste generation at the representative location on the methodology and data in the Navy EIS (DIRS 101941-USN 1996, p. 4-13). It evaluated potential impacts in terms of existing and projected waste handling and disposal procedures and regulations of relevant state and federal regulatory agencies. Manufacturers would comply with existing regulations to control the volume and toxicity of the liquid and solid waste they would produce. They would implement pollution prevention and reduction practices. The analysis evaluated only waste from the manufacture of repository components from component materials; it did not consider waste from mining, refining, and processing raw materials into component materials. The analysis assumed that component materials would be available from supplier stock regardless of the status of the repository project.

Liquid Waste

Liquid waste from manufacturing would consist of used lubricating and cutting oils from machining operations and cooling of cutting equipment. Consistent with typical existing facilities, manufacturers would recycle this material. They would treat water from cooling and washing operations and from ultrasonic weld testing by filtration and ion exchange, which would remove contaminants and permit its discharge to the sanitary sewer system. Table 4-37 lists the estimated amounts of liquid waste manufacturers would generate by shaping, machining, and welding the repository components. The average amount of liquid waste would be 7.5 metric tons (8.3 tons) per year during the 24-year manufacturing period and 4.5 metric tons (5.0 tons) per year during the 10-year period. The small quantities of waste from manufacturing would not exceed the capacities of existing equipment for waste stream treatment at the manufacturing facility.

Solid Waste

Table 4-37 lists the solid waste that manufacturing operations would generate. The average annual amount of solid waste would be about 1 metric ton (1.1 ton) per year during the 24-year manufacturing

Table 4-37. Annual average waste generated (metric tons) at the representative manufacturing location.

Measure		Liquid waste quantity	Solid waste quantity
24-year period[a]	Annual average	7.5	1.0
10-year period[b]	Annual average	4.5	0.62

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. The 24-year manufacturing period would be for all components except drip shields and would begin 2 years before emplacement.

b. The 10-year manufacturing period would be for drip shields only and would occur at repository closure.

period and about 0.62 metric ton (0.68 ton) per year during the 10-year period. The primary waste constituents would probably be metals: steel, nickel, molybdenum, chromium, and copper. Manufacturers could add these metals to existing manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium would arrive at the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, the representative manufacturing location would not generate or recycle depleted uranium waste and there would be no radiological health impacts. Lead for shielding would be cast between stainless-steel components for the shipping casks. It is unlikely that lead waste would occur in substantial quantities, and the manufacturers would recycle it.

4.1.14.5.6 *Environmental Justice*

DOE performed the environmental justice assessment to determine if disproportionately high and adverse health or environmental impacts from the manufacture of repository components would affect minority or low-income populations, as Executive Order 12898 requires. A disproportionately high impact (or risk of impact) in a minority or low-income community would be one that exceeded the corresponding impact on the larger community to a meaningful degree. This section summarizes the Navy EIS analysis (DIRS 101941-USN 1996, Section 4.8), which DOE adapted to the manufacturing of components for the proposed repository. It is the same analysis as that for the Yucca Mountain FEIS.

The assessment used demographic data from the areas of the five reference facilities to provide information on the degree to which minority or low-income populations could receive disproportionate effects. It used a geographic information system linked to 1990 Census data to define the composition of populations living within approximately 16 kilometers (10 miles) of the five facilities and to identify the percentage of minority and low-income individuals in each area. The assessment used the percentages of minority and low-income persons that comprise the population of the states in which the facilities are located as a reference.

The original analysis indicated that in one manufacturing facility location the proportion of minority population was higher than the proportion of the minority population in the state. The difference between the percentage of the minority population within the 16-kilometer (10-mile) radius and in the state was 1.5 percent (DIRS 101941-USN 1996, p. 4-18). DOE did not update the detailed evaluation in the Yucca Mountain FEIS, but evaluated more recent data to determine if there were notable changes to minority population distributions. According to Bureau of the Census data for 2003 (DIRS 181937-Bureau of the Census 2006, all; DIRS 181938-Bureau of the Census 2007, all), only one of the Metropolitan Statistical Areas where the reference facilities are located had a higher percent minority population than the applicable state as a whole. The difference in minority populations between the smaller area and of the state was 1.6 percent. Based on this more current census data, distribution of minority populations has probably remained similar to that for the FEIS. The conclusion remains the same; that is, DOE anticipates small impacts for the total population from manufacturing activities, so there would be no disproportionately high and adverse impacts to the minority population near the location of the representative facility.

The original analysis indicated that in one reference manufacturing facility location the proportion of low-income population was higher than the proportion of the low-income population in the state. The difference was 0.9 percent (DIRS 101941-USN 1996, p. 4-18). As noted above, DOE did not update the evaluation in the Yucca Mountain FEIS, but evaluated more recent data. Bureau of the Census data for the 1999 to 2000 timeframe (DIRS 181939-Bureau of the Census 2006 Table C-2; DIRS 181940-Bureau of the Census 2007, Table 690) indicate none of the Metropolitan Statistical Areas had a percent of low-income individuals higher than the applicable state as a whole. Based on the more recent data, distribution of low-income populations probably has remained similar, and possibly even improved, in comparison to that for the FEIS assessment. DOE anticipates small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population near the representative facility.

The analysis for this Repository SEIS determined that no high and adverse health and environmental impacts would occur to the population as a whole from the manufacture of repository components. Further, there were no identified impact pathways that would be specific to minority or low-income populations. Therefore, no high and adverse impacts to minority or low-income populations would be expected from these activities.

4.1.15 AIRSPACE RESTRICTIONS

The region of influence is the airspace over the analyzed land withdrawal area and airspace immediately adjacent, within approximately 48 kilometers (30 miles) of the repository's North Portal. This section describes DOE's requirement for airspace restrictions and the impacts of those restrictions.

4.1.15.1 Requirement for Airspace Restrictions

During the repository operations period, there would be spent nuclear fuel in buildings, in transportation casks, or on aging pads in protective overpacks at the proposed repository. DOE evaluated the potential for an aircraft crash into these areas to determine the probability of a release of radioactive material from the repository (Section 4.1.8 and Appendix E). Aircraft flights in the vicinity of the site are an important consideration in the accident analysis DOE conducted as part of this Repository SEIS and in the safety analysis documentation that DOE is preparing to support the license application. That analysis considers commercial, military, and general aviation aircraft activity in the area of the repository. It includes specification of limits on military aircraft flight altitude and number of flights per year over the repository. Specifically, the analysis assumed that a maximum of 1,000 fixed-wing military aircraft flights per year would cross the airspace defined by a 9.0-kilometer (5.6-statute-mile) radius from the North Portal of the repository at an altitude of at least 4,300 meters (14,000 feet) above mean sea level. It also assumes that no aircraft fly below 14,000 feet mean sea level within a 9.0-kilometer (5.6-statute-mile) radius of the North Portal.

As Chapter 3, Section 3.1.1.4, describes and Figure 4-9 shows, much of the airspace in the vicinity of Yucca Mountain is special-use restricted airspace. DOE has controlling authority over restricted airspace

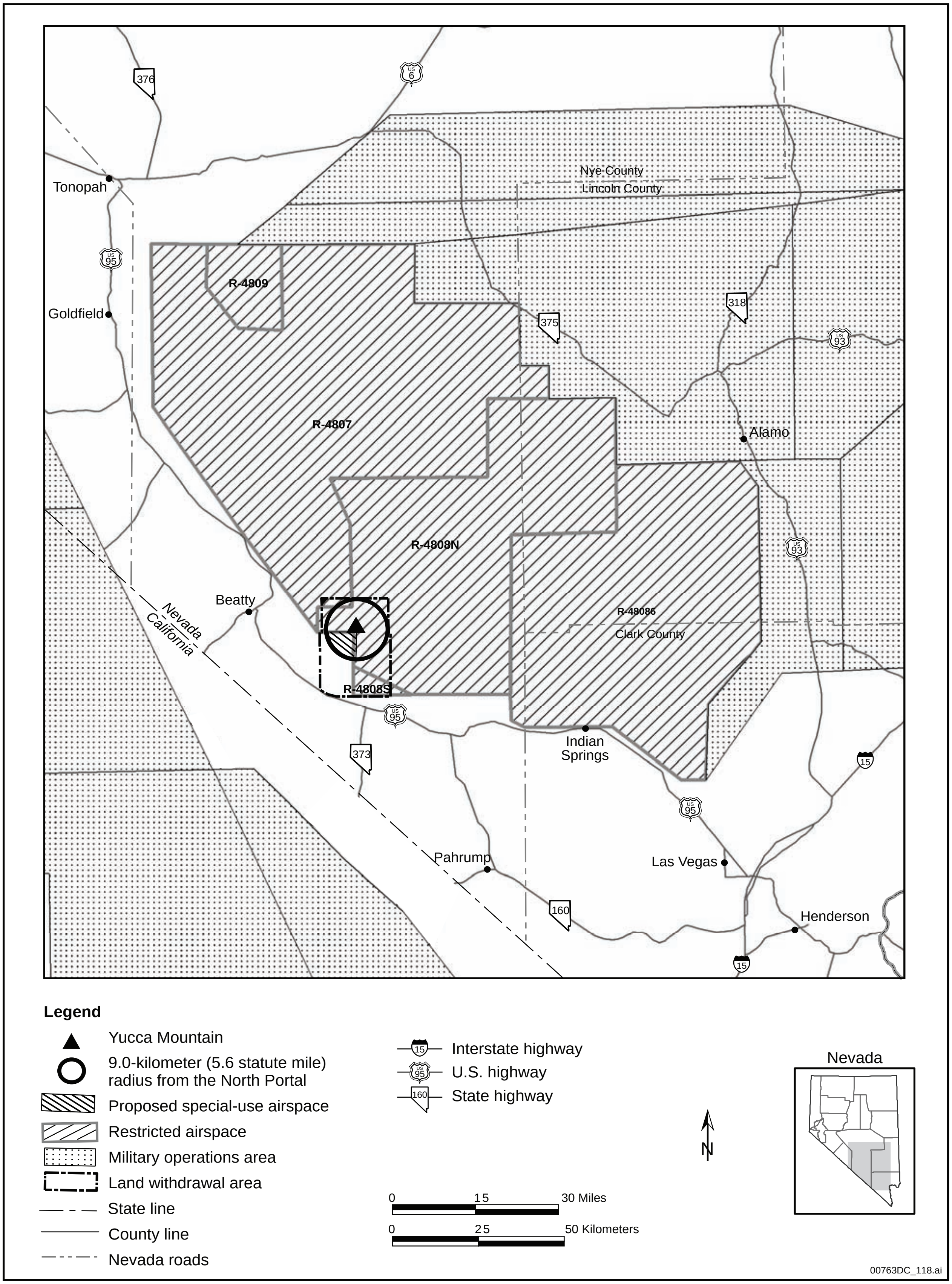


Figure 4-9. Airspace use near Yucca Mountain.

R-4808N, shown in Figure 4-9. Controlling authority means that DOE authorizes and specifies the use of the airspace although it does not provide air traffic control. Less than one-quarter of the airspace defined by a 9.0-kilometer (5.6-statute-mile) radius from the North Portal of the repository is not presently designated as restricted airspace. This "triangle" covers approximately 48 square kilometers (19 square miles) and is denoted on Figure 4-9 as "proposed special-use airspace." This area is currently categorized as Class A and Class G airspace but is not subject to over-flight by aviation traffic following point-to-point routes because such routes would infringe on the adjoining restricted areas. The Class A and Class G airspace located between the restricted areas and the military operations area (Figure 4-9) where commercial, military, and general aviation aircraft do fly point-to-point routes, is outside of the 9.0-kilometer (5.6-statute-mile) radius of the North Portal.

As noted above, the majority of the airspace within a 9.0-kilometer (5.6-statute-mile) radius of the North Portal is already within DOE restricted airspace. Flight activities within the DOE restricted airspace are coordinated to accommodate the needs of the U.S. Air Force and DOE. Because the air traffic restrictions for the repository would not be required for a number of years, DOE would monitor and take into consideration any modifications or additions to flight activities with the special-use airspace over the repository during the construction period.

If necessary to support repository operations, DOE would seek a special-use airspace designation from the Federal Aviation Administration for the 48-square-kilometer (19-square-mile) area described above. In addition, airspace restrictions could include agreements with the U.S. Air Force and other users to manage traffic in the vicinity of the repository. The accident analysis conducted as part of this Repository SEIS (Section 4.1.8 and Appendix E) assumed that such flight restrictions would occur.

Depending on the type of special-use airspace requested, Federal Aviation Administration regulations may not require additional analyses under the *National Environmental Policy Act*, as amended (NEPA) (42 U.S.C. 4321 et seq.). DOE has analyzed the impacts of designating the 48-square-kilometer area as special-use airspace in this Repository SEIS for completeness. The requested special use airspace designation of the 48-square-kilometer (19-square-mile) resource area is not applicable to other resource areas.

4.1.15.2 Impacts to Airspace Use

If DOE acquired a special-use airspace designation as described above, the Department would gain exclusive control and use of the approximate 48-square-kilometer (19-square-mile) area in addition to the existing 4,400-square-kilometer (1,700-square-mile) restricted airspace of the Nevada Test Site (Chapter 3, Section 3.1.1.4). This would result in less than a 1.4-percent increase in DOE special-use airspace in the area, and less than a 0.3 percent increase in DOE and U.S. Air Force combined restricted airspace.

The designation of the proposed airspace as special-use airspace would prohibit flights in a small portion of the west low-altitude tactical navigation area used by U.S. Air Force A-10 aircraft and helicopters; there are currently about 30 flights per week.

Use of the airspace by the public is relatively light in comparison with other areas in Nevada due to the airspace being bounded on the north and east by the existing restricted areas of the Nevada Test and Training Range and the Nevada Test Site. Due to the small area of the proposed special-use airspace and the shape of the surrounding restricted areas, there would be little to no impact on general aviation aircraft that could fly within this area (small piston-engine aircraft, helicopters, and gliders). There would be no impact on commercial or general aviation flying point-to-point routes in the area, because these aircraft do not fly in this airspace. Overall, impacts to airspace use from designation of the proposed special-use airspace would be small.

In a separate action, DOE would continue to work with the U.S. Air Force to accommodate their need to fly through the Nevada Test Site airspace. DOE would authorize specific Air Force activities over the repository consistent with the repository safety analysis. DOE plans to continue to allow military flights over the repository by fixed-wing aircraft with the following restrictions:

- A maximum of 1,000 flights per year above 4,300 meters (14,000 feet) above mean sea level altitude;
- A prohibition of maneuvering of aircraft—flight is to be straight and level;
- A prohibition of carrying ordnance over the flight-restricted airspace; and
- A prohibition of electronic jamming activity over the flight restricted airspace.

Based on coordination with and input from the U.S. Air Force, impacts to military airspace use of the Nevada Test Site airspace from the restrictions listed above would be small.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency

Section 122 of the *Nuclear Waste Policy Act*, as amended (NWPA) (42 U.S.C. 10101 et seq.) requires DOE to maintain the ability to retrieve emplaced spent nuclear fuel and high-level radioactive waste. The NRC specifies further that DOE must be able to maintain a retrieval period for at least 50 years after the start of emplacement [10 CFR 63.111(e)]. Although DOE does not anticipate the need to retrieve spent nuclear fuel or high-level radioactive waste and retrieval is not part of the Proposed Action per se, DOE would, as required, retain the ability to retrieve waste for at least 50 years after the start of emplacement or until there is a decision to close the repository permanently. For this reason, the Yucca Mountain FEIS analyzed potential impacts to environmental resources from retrieval.

According to *Concepts for Waste Retrieval and Alternate Storage of Radioactive Waste* (DIRS 182322-BSC 2007, all), the current concept for waste retrieval has not changed from that DOE analyzed in the Yucca Mountain FEIS. Operations to retrieve spent nuclear fuel and high-level radioactive waste from the repository to the surface would continue to be the reverse of those for emplacement using equipment, such as the transport and emplacement vehicle, as Chapter 2, Section 2.1.2.1.8 of this Repository SEIS describes. As before, DOE would move waste packages to the surface, load them into concrete storage modules, and move them to the Waste Retrieval and Storage Area. Because the concept of retrieval has not changed from that of the Yucca Mountain FEIS, the environmental impacts DOE reported in Section 4.2 of that document continue to represent those that could occur during retrieval.

4.3 Infrastructure Improvements

DOE identified the need to repair, replace, or improve certain elements of the infrastructure that currently exist on the site to help ensure safety under a high level of activity. These proposed safety improvements were based on assessments of the condition of the existing infrastructure; some parts of the infrastructure at Yucca Mountain are nearing, or in some cases have exceeded, their design and operational lifetimes. Because DOE has mandated operational restrictions on continued scientific activities, testing, and maintenance to maintain the safety of workers, regulators, and visitors, the infrastructure improvements would be necessary before construction of the Yucca Mountain Repository if DOE decided to lift current operational restrictions.

The proposed infrastructure improvements are subsets of larger actions DOE has defined as part of the Proposed Action. In the Proposed Action, DOE has identified the need for two 138-kilovolt transmission lines (with a capability of boosting to 230-kilovolts, if needed). Under the proposed infrastructure improvements, DOE would construct one 138-kilovolt transmission line. The Proposed Action defines a four-lane paved access road, while the proposed infrastructure improvements are for a two-lane road.

Section 4.3.2 summarizes the potential environmental impacts of the infrastructure improvements in the context of the larger elements of the Proposed Action. The corresponding Proposed Action elements are addressed in the applicable subsections in Section 4.1. In that the infrastructure improvements would generally be smaller in scope and have shorter construction periods, the potential impacts would generally be less than those for the corresponding actions under the Proposed Action. Because the proposed infrastructure improvements would occur before construction of the repository, the potential impacts would not be concurrent with those of construction and operation of the repository. Chapter 10 covers short-term uses, long-term productivity, and irreversible or irretrievable commitment of resources as part of the Proposed Action.

In June 2006, DOE issued the *Draft Environmental Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada* (DIRS 178817-DOE 2006, all). DOE has since decided not to finalize the environmental assessment, but rather to incorporate the actions it evaluated into this Repository SEIS. In the draft environmental assessment, DOE provided two route and construction options for the improvement of access roads and a 138-kilovolt transmission line (DIRS 178817-DOE 2006, all), as well as the improvement of several facilities. Since the issuance of the draft environmental assessment, additional transmission line routes have been identified but little detail has been developed. In the draft environmental assessment, DOE identified two options for access road improvements. This Repository SEIS discusses only DOE’s preferred option. The road improvement option to the preferred option differed only in the length of the road; it would be about 13 kilometers (8 miles) longer than that for the preferred option. The Department concluded that the second option presented in the draft environmental assessment would not be technically practicable or economically feasible. The draft environmental assessment serves as the basis for identification of proposed infrastructure improvements, but the design and operational plans for these improvements, along with any potential options, are under development.

DOE developed the following proposed infrastructure improvements after completion of the Yucca Mountain FEIS:

- The building of new and replacement roads that would include a two-lane access road from U.S. Highway 95 at its intersection with State Route 373 to Gate 510. This is the preferred option in the draft environmental assessment except that the preferred option did not align the access road with State Route 373, as is the current proposal. Chapter 2, Section 2.1.6.1 describes roads under the Proposed Action. Option B as described in the draft environmental assessment is not included in the Repository SEIS because the Department no longer considers it a reasonable option.

- The building of a new 138-kilovolt transmission line to existing facilities from the Lathrop Wells switch station. This was the preferred option in the draft environmental assessment. Chapter 2, Section 2.1.4.4.1 describes the electrical power and distribution system under the Proposed Action. DOE has identified several other options to provide upgraded electrical services to the Yucca Mountain Repository before the start of construction, if needed. Other options could start on the Nevada Test Site and then move to the central operations area. Because DOE could require additional switchyards and substations, options would require further definition in cooperation with one or more electric power vendors and therefore are uncertain at this time.

- The developing of a central operations area to replace the existing infrastructure that has outlived its design life. Chapter 2, Section 2.1.4.3.6 describes the central operations area under the Proposed Action.

- The repairing of erosion damage to the existing 0.061-square-kilometer (15-acre) Equipment Storage Pad. This pad is not within either the North or South Portal areas and its improvement is not part of the Proposed Action.

- The building of a Sample Management Facility near Gate 510 of the Nevada Test Site on Bureau of Land Management land outside the analyzed land withdrawal area. Chapter 2, Section 2.1.6.2 describes the sample management facility under the Proposed Action.

If DOE did not implement these proposed infrastructure improvements in the near term, DOE would continue to operate the Yucca Mountain Project using the existing infrastructure with appropriate mitigation measures to protect worker health and safety. DOE would continue maintenance and replacement of infrastructure on an as-needed basis only, until the NRC decided whether to authorize construction of a repository at Yucca Mountain.

4.3.1 PROPOSED INFRASTRUCTURE IMPROVEMENTS

Sections 4.3.1.1 through 4.3.1.5 describe each proposed infrastructure improvement.

4.3.1.1 Road Construction

DOE would build several new roads and replace several existing roads (Figure 4-10), which would total about 40 kilometers (25 miles) of new and replacement paved roads. DOE would first build a new 13.7-kilometer (8.5-mile) two-lane paved access road from a point 3.7 kilometers (2.3 miles) north of Gate 510 on the Nevada Test Site to a point about 0.8 kilometers (0.5 miles) east of Fortymile Wash. Second, theDepartment would build a new 2.1-kilometer (1.3-mile) two-lane paved road to the crest of Yucca Mountain. DOE would move the existing access road to Gate 510 approximately 0.39 kilometer (0.24 mile) to the southeast to line up with the State Route 373 and U.S. High 95 intersection (Figure 4-10). A total of about 0.55 square kilometer (135 acres) would be disturbed.

Road construction would require borrow material that DOE would obtain from the existing excavated rock storage pile near the North Portal, existing aggregate pits west of H Road along Fran Ridge, a new borrow site at an unspecified location, or a combination of these sources. The two roads would disturb a total of about 0.54 square kilometer (135 acres).

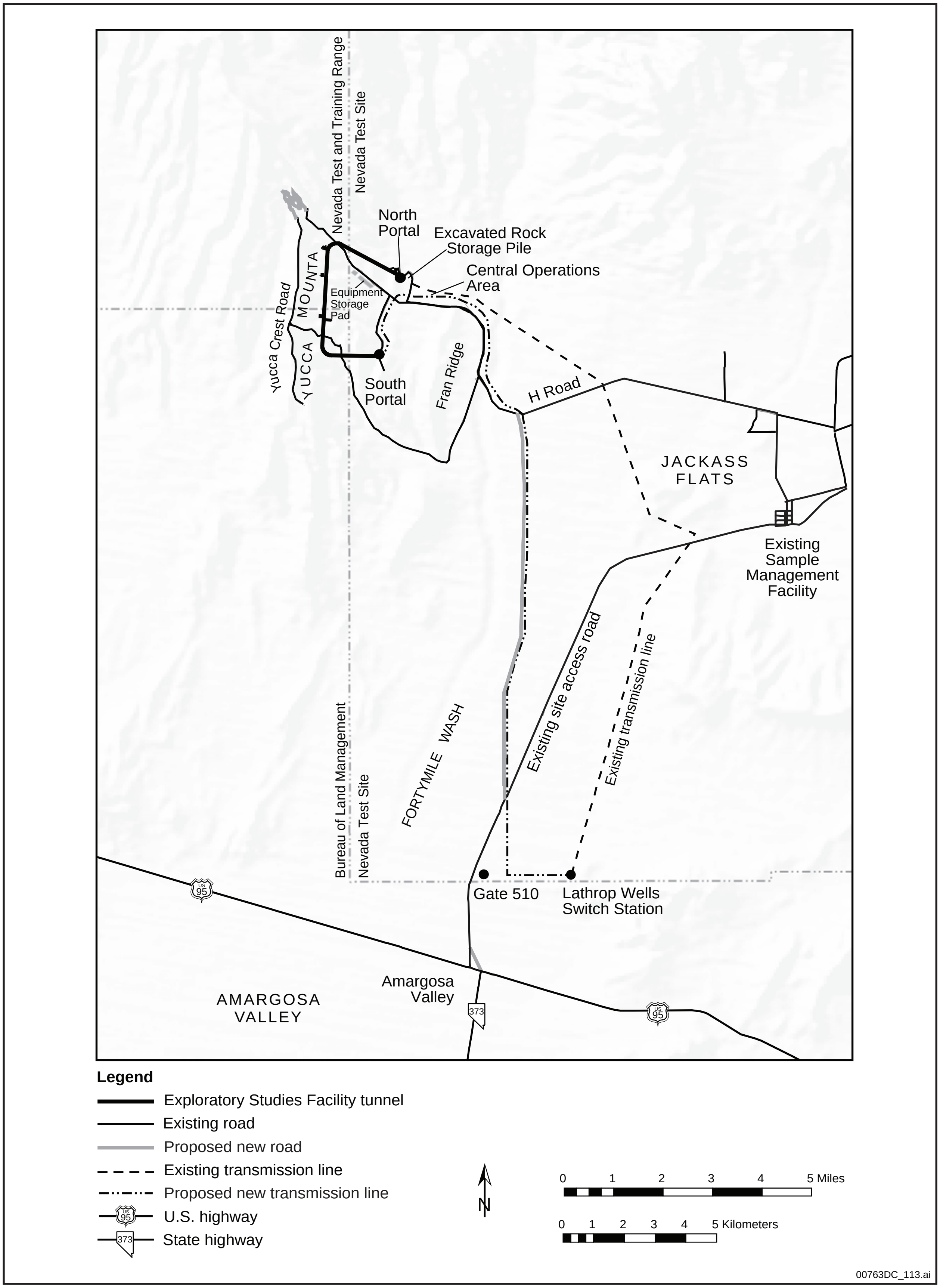


Figure 4-10. Proposed infrastructure improvements.

The Department would drill cores along the centerline of each new roadbed at intervals based on field conditions. Workers would remove vegetation and about 15 centimeters (6 inches) of topsoil by blading and would stockpile the soil for use in reclamation. Heavy machinery would level high points along the roadbeds and move the excess material to low points to balance cut and fill. DOE would install road shoulders, erosion controls, drainage culverts, riprap, and ditches in accordance with best management practices. Construction and safe operation of part of the new road to the crest of Yucca Mountain could require drilling and blasting and retaining walls. A strip 11 meters (36 feet) wide for the crest road and 15 meters (50 feet) wide for the access road would be compacted and paved. A 46-centimeter (18-inch)-thick layer of fill would be placed on the roadbed and compacted, after which a 41-centimeter (16-inch)-thick layer of aggregate would be placed over the fill and compacted; last, an 18-centimeter (7-inch)-thick layer of asphalt would be applied to the road surface. The total width of the disturbance for these new roads and shoulders would be about 37 meters (120 feet) for the access road and about 18 meters (60 feet) for the crest road.

The Department would replace about 19 kilometers (12 miles) of existing access road (H Road) and about 4.7 kilometer (2.9 mile) of the existing crest road with two-lane asphalt roads. The replacement would include construction of a culvert (generally designed to accommodate a 100-year flood) at Fortymile Wash. The existing asphalt roadbed would be excavated and stockpiled for possible use as fill material. A total of about 0.34 square kilometers (85 acres) would be disturbed.

4.3.1.2 Transmission Line Construction

The Department proposes to install a 138-kilovolt transmission line from the existing Lathrop Wells switch station to a proposed substation at the central operations area (Figure 4-10). The total length of the transmission line from the Lathrop Wells switch station to the central operations area would be about 29 kilometers (18 miles). This is the preferred option described in the draft environmental assessment. From the switch station, the transmission line would extend due west about 2.4 kilometers (1.5 miles) along the boundary of the Nevada Test Site. It would then turn north for about 3.2 kilometers (2 miles) before it intersected the proposed new access road. From this point, the transmission line would extend 14 kilometers (8.5 miles) along the new access road to its junction with the existing access road about 0.8 kilometer (0.5 mile) east of Fortymile Wash. From this point, the transmission line would extend another 8.9 kilometers (5.5 miles) along the existing access road, cross Fortymile Wash, and end at the central operations area (Figure 4-10). From the substation at the central operations area, DOE would install two 13.8-kilovolt transmission lines: an approximately 1.6-kilometer (1-mile) replacement line to power the existing Exploratory Studies Facility equipment and a 3.2-kilometer (2-mile) line to a substation at the South Portal to provide power to operate exhaust fans that currently function intermittently on generator power. Each transmission line would extend along existing roads. The proposed substations at the central operations area and the South Portal would each require a pad of about 30 by 30 meters (100 by 100 feet). DOE would not remove existing distribution equipment (the poles and cables) and could maintain it for backup power supply.

4.3.1.3 Central Operations Area

The Department would develop a central operations area about 0.8 kilometer (0.5 mile) southeast of the North Portal for all operations, which would include support and replacement of underground infrastructure in the Exploratory Studies Facility (Figure 4-10). Proposed construction would occur on about 0.12 square kilometer (30 acres) of land DOE has used for equipment storage and lay down. On completion of this construction, the Department would dismantle and dispose of existing temporary structures and utilities at the North Portal and the existing Field Operations Area, which would be obsolete. The improvements for the replacement of existing infrastructure would enhance the safety margins for continued near-term scientific exploration, testing, and maintenance.

As much as 115,000 cubic meters (150,000 cubic yards) of fill material would be transported to the area, compacted, and graded for proper drainage. The fill material would be from the excavated rock storage pile near the North Portal, existing aggregate pits (west of H road along Fran Ridge), a new borrow site at an unspecified location, or a combination of these sources. The fill would be crushed and screened at the source location. After placement and grading of the fill material, DOE would construct five new support buildings and install utilities (power, water, sewer, and communications). The five support buildings would include a 4,000-square-meter (43,000-square-foot) field operations center for offices, training, computer operations, and emergency facilities; a 930-square-meter (10,000-square-foot) incident-response station for fire and medical support; a 4,000-square-meter craft shop and annex for maintenance and repair operations; a fuel and vehicle wash facility; and a 3,300-square-meter (35,000-square-foot) warehouse and material storage yard. The fuel facility would have space for refueling islands to supply diesel, gasoline, propane, and compressed natural gas and a separate facility to wash vehicles. DOE would pave the areas around each building with asphalt to control dust. The entire site would be fenced and exterior lighting would be installed. These buildings would replace the more than 100 temporary structures (for example, storage containers, trailers, and tents) that DOE currently uses for workshops, equipment fabrication and repair, warehousing, and offices.

The existing options for the disposal of temporary structures would include an the Nevada Test Site landfills in Areas 23 and 9, and the Crestline landfill in Lincoln County and Apex landfill in Clark County, which the counties operate. Nye County is in the process of siting new landfill locations, so DOE could also work cooperatively with the county to site and permit a new facility. Chapter 3, Section 3.1.12.1 provides information on solid waste disposal sites and their capacities.

4.3.1.4 Equipment Storage Pad

DOE would repair the 0.061-square-kilometer (15-acre) equipment storage pad approximately 1.6 kilometer (1 mile) southwest of the North Portal, which has been damaged over the years by natural erosion (Figure 4-10). The Department would repair this damage and improve drainage on the storage pad by leveling the area with up to 3,800 cubic meters (5,000 cubic yards) of borrow material from the existing excavated rock storage pile near the North Portal, existing borrow pits, a new borrow site at an unspecified location within 24 kilometers (15 miles), or a combination of these sources.

4.3.1.5 Sample Management Facility

DOE would construct a new Sample Management Facility near Gate 510 on Bureau of Land Management land outside the analyzed land withdrawal area. This facility would house a variety of samples from studies that included rock cores. The building would cover about 3,900 square meters (42,000 square feet) within a 3,300-square-meter (35, 000-square-foot) fenced area. Land disturbance would affect about 0.012 square kilometer (3 acres).

4.3.2 ENVIRONMENTAL IMPACTS

This section describes the potential environmental impacts for the proposed infrastructure improvements. Table 4-38 lists the estimated land disturbances, water requirements, and workforce for each proposed improvement.

Table 4-38. Estimated disturbances, water requirements, and workforce.

Infrastructure improvement	Disturbances (acres)[a]	Water requirements[b] (acre-feet)	Estimated new workers during construction[c]
Roads	220	200	40
Transmission line	30	6	16
Central operations area	0	22	100
Equipment storage pad	0	< 1	10
Sample Management Facility	3	< 1	30
Totals	253	230	196

Source: DIRS 178817-DOE 2006, p. 15.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Some of the land in this category has experienced small disturbances from previous activities.
b. The analysis assumed that construction would take 2 years, even though in some cases the activities would be complete sooner.
c. The workforce for the central operations area could include persons who already work on the Yucca Mountain Project.

4.3.2.1 Land Use and Ownership

Section 4.1.1 describes potential land use and ownership impacts from the Proposed Action. Under the Proposed Action, DOE would require a four-lane paved access road and two 138-kilovolt transmission lines; infrastructure improvements would require a two-lane access road and one 138-kilovolt transmission line.

The proposed infrastructure improvements would have negligible effects on existing or future land uses. Most of the affected land would be on the Nevada Test Site and the Nevada Test and Training Range. As Chapter 3, Section 3.1.2 describes, the U.S. Air Force has issued a right-of-way reservation that authorizes DOE to use certain land for the Yucca Mountain Project, which would include the crest road. The authorized use of Test Site land is based on a 2002 management agreement between DOE’s Nevada Operations Office and Office of Repository Development. Because the improvements would not change the nature of current activities at Yucca Mountain, the actions would not affect operations at either the Test Site or the Range.

The proposed road upgrades could include the development of an aggregate pit at an unspecified location. The *Materials Act of 1947* governs access to and use of common varieties of sand, stone, and gravel on public lands by federal agencies; the Act authorizes the Bureau of Land Management to issue free-use permits for these materials. If the Department required the development of this pit, it would apply to the Bureau for a free-use permit. DOE would not open a new pit if an adequate quantity and quality of aggregate was available from the existing aggregate pits at Yucca Mountain west of H Road along Fran Ridge.

DOE would construct the Sample Management Facility near Gate 510 on Bureau of Land Management land outside the analyzed land withdrawal area, move the contents of the existing Sample Management Facility at the Field Operations Center, and dismantle the existing facility. The facility would require about 0.012 square kilometers (3 acres). Construction of the new facility would not affect the use of public land in the area.

4.3.2.2 Air Quality

Section 4.1.2 describes potential nonradiological air quality impacts from the Proposed Action. The potential environmental impacts from the infrastructure improvements would be smaller than those for the Proposed Action for criteria pollutants.

The potential impacts to air quality from the proposed infrastructure improvements would be small. Sources of air pollutants from the proposed improvements would be (1) dust from surface grading for roads, possible blasting for parts of the new road to the crest of Yucca Mountain, possible relocation or reuse of the existing excavated rock storage pile near the North Portal, vehicle travel on paved and unpaved roads, and wind erosion, and (2) combustion of fossil fuel by diesel- and gasoline-powered construction equipment.

Potential air quality impacts would result primarily from the disturbance of approximately 1 square kilometer (250 acres) of land (Table 4-38). Based on the results of dispersion modeling for this Repository SEIS, gaseous pollutants from fuel-burning equipment would be well below regulatory standards. Therefore, the primary criteria pollutant of concern would be PM_{10}. Emissions for the Proposed Action during the construction period would result in concentrations of PM_{10} that would be no more than 60 percent of the standards. Therefore, the air quality impacts from infrastructure improvements would also be well within the PM_{10} standard.

Certain forms of hazardous silica dust could disperse into the atmosphere if DOE used the excavated rock storage pile near the North Portal for road or storage-pad construction. Cristobalite is one of several forms of crystalline silica that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale the particles while performing their tasks. The Department would monitor the environment at and near the storage pile to ensure that workers were not exposed to harmful concentrations of this dust. If engineering controls were unable to maintain safe dust concentrations, DOE would use administrative controls such as access restrictions or respiratory protection (dust suppression, air filters, and personal-protective gear) until engineering controls could reestablish safe conditions. DOE would apply the same monitoring and engineering controls to the storage piles as it would to construction sites where the silica could be present. Section 4.1.2.1 discusses the potential impacts related to cristobalite.

4.3.2.3 Hydrology

Section 4.1.3 describes the potential environmental impacts to hydrological resources at Yucca Mountain from the Proposed Action. This infrastructure improvement analysis evaluated potential impacts to these resources in three areas: surface water, groundwater quality, and water demand.

Water demand for dust suppression would be smaller than that for the construction of the four-lane road to support repository construction and operation and would not be concurrent with water demand for

Repository construction. Potential contamination of groundwater and the volume of surface runoff would also be smaller than that under the Proposed Action.

4.3.2.3.1 *Surface Water*

Potential impacts to surface water, drainages, and floodplains from the infrastructure improvements would be small. Disturbed and loosened ground would generate less runoff and more infiltration and, possibly be more susceptible to erosion during heavy precipitation, but this would only be during construction. At the completion of construction, DOE would either cover most disturbed areas with impermeable surfaces (structures or asphalt) or compact them, at which time runoff rates could increase. In any case, changes to infiltration and runoff rates would be limited to relatively small areas of disturbed land; DOE would take precautions during construction to minimize erosion. DOE would control the use of petroleum, oil, lubricants, and other hazardous materials during construction; the Department would promptly clean up spills and remediate the soil and alluvium. The designs of road crossings at washes would maintain the flow of water through culverts and prevent erosion up- and downstream of the crossings. The proposed road upgrades would require improvement of the access road that crosses Fortymile Wash and would extend along Drill Hole Wash to near the point it is joined by Midway Valley Wash. This construction would affect both Fortymile and Drill Hole washes, including their floodplains, but the impacts would be small. Appendix C contains the floodplain and wetlands assessment for this Repository SEIS. Appendix C, Section C.2.2 discusses proposed infrastructure improvements.

Improvement of the road that crosses Fortymile Wash would require placement of fill in the channels of the wash. Raising the road across Fortymile Wash would require about 0.00081 square kilometer (0.2 acre) of new fill. Replacement of the access road next to Drill Hole Wash just north of its confluence with Fortymile Wash could require modification of the flow channel of Drill Hole Wash. Improvement of the access road in this area could have beneficial effects on surface-water flow because the drainage area design and construction would reduce erosion along the existing road and accommodate the combined flow from Drill Hole and Midway Valley washes more appropriately. Culverts (which would generally be designed to accommodate a 100-year flood) would have small impacts on surface water or other resources because DOE would design and construct them to minimize erosion and the associated sediment transport and to accommodate the flow in the washes during storms.

The Department would, if required, obtain a permit from the U.S. Army Corps of Engineers for construction in waters that meet the criteria for jurisdictional waters of the United States. Fortymile Wash, a tributary of the Amargosa River, and some of its tributaries, in and near the geologic repository operations area might, be waters of the United States.

4.3.2.3.2 *Groundwater Quality*

The proposed infrastructure improvements would have small impacts on the quality of groundwater because the water table varies from 270 to 760 meters (900 to 2,500 feet) below the surface. DOE would remediate inadvertent spills of hazardous materials and would not allow such material to reach the water table.

4.3.2.3.3 *Water Demand*

The quantity of groundwater necessary for the proposed infrastructure improvements would be 284,000 cubic meters (230 acre-feet) per year for a 2-year period. DOE would pump the water from wells at

Yucca Mountain within the western two-thirds of the Jackass Flats basin. Of the water demand over the 2-year period an average of about 80 percent would be for access road construction including compaction of material, and about 17 percent would be for dust suppression. Less than 4 percent would be for construction workers, who would generally not shower on the site (DIRS 181232-Fitzpatrick-Maul 2007, all).

The lowest estimate of perennial yield for this part of the Jackass Flats basin is 715,000 cubic meters (580 acre-feet). The impacts to regional water availability would be less than the estimated minimum perennial yield for the Jackass Flats basin. The water demand estimates in Section 4.1.3 include the estimates for construction of a four-lane access road.

4.3.2.4 Biological Resources and Soils

Section 4.1.4 describes potential environmental impacts from the Proposed Action on biological resources and soils. Potential impacts to biological resources from the proposed infrastructure improvements involve four areas: (1) vegetation, (2) wildlife, (3) special-status species, and (4) soils. Impacts to plants, animals, and special-status species would be the same or smaller than those under the Proposed Action in that there would be less land disturbance and habitat loss and construction periods would be shorter.

4.3.2.4.1 *Vegetation*

Potential impacts to vegetation from the infrastructure improvements would be small. Construction of the access road and transmission line would remove vegetation on about 1 square kilometer (250 acres) (Table 4-38). Soil compaction would change the physical structure of the soil and would probably reduce the reestablishment of native species. Dust from construction would stress downwind plant communities by covering leaves and reducing photosynthetic capacity. This impact would be temporary and would end when sufficient rain and wind removed the dust from the leaves.

Clearing native vegetation and disturbing the soil would create habitat for nonnative invasive plant species. These plants often out-compete native species and generally have little or no value for native wildlife. The seeds of nonnative species can spread into surrounding undisturbed areas by wind and wildlife, as well as by workers and construction equipment. Because many nonnative plant species are annuals or grasses that generate large amounts of litter, the potential for fires is generally higher than in nearby areas of native vegetation. After construction was complete, DOE would revegetate unneeded disturbed areas (Section 4.1.4) and would control invasive species on those sites.

4.3.2.4.2 *Wildlife*

Potential impacts to wildlife from the proposed infrastructure improvements would be small. The proposed road and transmission line construction would disturb about 1 square kilometer (250 acres) much of which earlier activities had disturbed (Table 4-38). These are very small areas in comparison to the large amount of surrounding undisturbed, similar habitat.

Loss of habitat would adversely affect some large and small animals (e.g., burros, mule deer, birds, and reptiles). Construction noise could startle birds and other animals, including game species, and they would tend to avoid contact with humans by moving to other areas. Construction equipment could crush or smother animals that use underground habitats, such as rodents, snakes, desert tortoises, kit foxes, and burrowing owls. Wildlife deaths could also occur from collisions with vehicles traveling to and from

Yucca Mountain. New manmade structures would provide additional perches for raptors, which could result in an increase in predation of lizards, snakes, rodents, and tortoises.

If construction occurred during the migratory bird nesting season (generally May 1 to July 15 at Yucca Mountain), DOE would have a qualified biologist survey areas before it began activities in those areas. If the survey found active nests, DOE would delineate a buffer zone around the nests in which it would avoid disturbance until the young birds fledged. Therefore, the proposed activities would be unlikely to result in deaths or otherwise to disturb nesting migratory birds.

4.3.2.4.3 *Special-Status Species*

Potential impacts to special-status species from the proposed infrastructure improvements would be small. The desert tortoise is the only species (animal or plant) in the affected area that the U.S. Fish and Wildlife Service lists as threatened under the Endangered Species Act. There are no listed endangered species. The Fish and Wildlife Service concluded in a biological opinion issued in 2001 that construction activities at Yucca Mountain would be unlikely to jeopardize the Mojave population of the desert tortoise. DOE included that opinion in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Appendix O). However, construction activities could kill or injure some tortoises, and there could be an increase in the number of ravens or other predators of tortoises due to additional perching sites on manmade structures. DOE would implement the terms and conditions in the Fish and Wildlife Service biological opinion to protect the desert tortoise.

Chapter 3, Table 3-7 lists other special-status animal species that do or might occur at Yucca Mountain. The proposed infrastructure improvements would result in the loss of habitat for a small number of chuckwallas, loggerhead shrikes, burrowing owls, and some other migratory birds. These species occur widely in neighboring undisturbed areas, so the overall impacts to these species would be small. The described actions to protect migratory birds would also protect these species from direct mortality or destruction of active nests.

4.3.2.4.4 *Soils*

Construction and operation of the infrastructure improvements would result in disturbed land and expose soil materials to potential loss by wind and water erosion. DOE would stockpile topsoil to reclaim disturbed areas. To further minimize soil loss, the Department would control fugitive dust by water spraying, chemical treatment, and wind fences. Control of storm water runoff would minimize soil erosion. Because the areas of disturbance would be smaller for the infrastructure improvements than for the Proposed Action, the potential for soil loss would be smaller.

4.3.2.5 Cultural Resources

Land disturbances for proposed infrastructure improvements could have impacts to cultural resources. DOE surveyed the alignment of the proposed new access road during 2005 and 2006 to determine the nature and extent of cultural resources. Because of these surveys, DOE moved the corridor for the access road east to avoid cultural sites near Fortymile Wash.

As Section 4.1.5 of this Repository SEIS states, the Yucca Mountain FEIS concluded that 51 archaeological sites were recommended eligible for inclusion in the *National Register of Historic Places* by DOE. DOE has revised this number to 232 archaeological sites. The revised number reflects recent investigations for the U.S. Highway 95 access road and a reevaluation of the importance of obsidian artifacts. Recent studies suggest that obsidian artifacts can provide important information on prehistoric American Indian settlement systems. The large increase in the number of eligible archaeological sites since completion of the FEIS reflects this finding and includes extractive localities, processing localities, or manufacture stations where obsidian was used as a tool stone material.

Before beginning other land disturbances (for example, expansions at existing sites and alignments), the Department would conduct preconstruction surveys to identify cultural sites in the affected areas. The Department would then evaluate identified sites for their importance and eligibility for inclusion in the *National Register of Historic Places*.

4.3.2.6 Socioeconomics

Section 4.1.6 describes the potential socioeconomic impacts of the Proposed Action. The socioeconomic impacts of the infrastructure improvements would be smaller than those under the Proposed Action because the associated construction workforce would be smaller and the construction period would be shorter.

The proposed infrastructure improvements would have small socioeconomic impacts. Construction would require a maximum of 196 workers for 2 years (Table 4-38). Most of these workers would probably come from the metropolitan Las Vegas area. In comparison, construction employment at a repository at Yucca Mountain would peak at 2,590 jobs, of which 1,090 would be newly created. That level of employment would be less than a 0.2-percent increase in total regional employment and, therefore, would have even smaller socioeconomic impacts.

Although Yucca Mountain site employment numbers have dropped significantly since late 1995, the estimated workers necessary for the infrastructure improvements could come from the existing workforce and would have little impact on the regional economy or on employment, economics, population, housing, and public services.

4.3.2.7 Occupational and Public Health and Safety

Section 4.1.7 describes the potential health and safety impacts to workers (occupational impacts) and to members of the public (public impacts) from the Proposed Action. It also reports the most recent accident rates from the CAIRS database. Infrastructure improvements would employ fewer people and have a shorter construction period; therefore, the potential impacts would be smaller than those of the Proposed Action. There would be no radiological issues in relation to the improvements. In addition, the purpose of the infrastructure improvements would be to enhance and ensure that continued scientific testing, exploration work, and maintenance could be done safely.

From an occupational health and safety standpoint, the types of potential health and safety impacts workers encountered would include industrial hazards common to construction work sites and potential exposure to naturally occurring cristobalite.

The possibility that DOE would use material from the excavated rock storage pile near the North Portal for road construction and leveling of the site for the central operations area could result in exposure to cristobalite. Based on the content of cristobalite in the rock, the storage pile could have a cristobalite content between 18 and 28 percent. DOE would implement engineering controls to limit dust emissions, continually monitor concentrations and, if monitoring showed concentrations were too high or above the threshold limits, operations would be limited. If engineering controls were unable to maintain dust concentrations below the limits, DOE would use administrative controls such as access restrictions, employee rotations, and respiratory protection until engineering controls could reestablish safe conditions. DOE would apply the same engineering and administrative controls to construction sites where silica could be present as it would for the storage pile. Section 4.1.2.1 discusses potential impacts in relation to cristobalite.

Potential health impacts to members of the public would occur from emissions from fossil fuels and PM_{10}. In both cases the potential impacts would be small (Section 4.3.2.2).

4.3.2.8 Accident Scenarios

There would be no radiological impacts from any accident that involved the infrastructure improvements. Impacts from industrial accidents are included in the occupational health and safety impact discussions in Sections 4.3.2.7 and 4.1.7.1.

4.3.2.9 Noise

Section 4.1.9 describes potential noise impacts to workers and the public from the Proposed Action. Noise impacts from the infrastructure improvements would be similar to those estimated for the Proposed Action; however, these impacts would be temporary. Noise from construction activities for a two-lane road would not be notably less than that for a four-lane road. The construction of the offsite facilities would also be similar to that of the Proposed Action.

Sources of noise would include construction of the access road from U.S. Highway 95 to Gate 510, an electrical transmission line, and the Sample Management Facility. Activities would involve typical construction equipment (such as bulldozers, graders, loaders, and pavers). This type of equipment generates noise at 85 dBA at 15 meters (50 feet). Noise and sound levels would be typical of new construction activities and would be intermittent. The distance from Gate 510 to the intersection of Nevada State Route 373 and U.S. Highway 95 is approximately 3.2 kilometers (2 miles). The nearest permanent residents would be in the town of Amargosa Valley, which is southwest of the intersection of U.S. Highway 95 and State 373. The analysis assumed the maximally exposed individual would be 100 meters (300 feet) from off-site construction activities. Section 4.1.2.1 discusses this individual. Because of the distance between construction activities and receptors, DOE does not expect noise impacts to the public from the construction of infrastructure improvements.

Traffic noise on the access road would not exceed or significantly add to the existing traffic noise on U.S. Highway 95. Noise from operations after construction would be typical of commercial environments and would have no impacts.

4.3.2.10 Aesthetics

Section 4.1.10 describes the potential aesthetics impacts of the Proposed Action. Aesthetics impacts from the infrastructure improvements would be similar to those DOE estimated for the Proposed Action because the landscape intrusions would be of the same type but could have a smaller scope. The transmission line would be a noticeable linear feature, but most of it would traverse remote areas.

Construction equipment, facilities, and activities would be potential sources of impacts to visual resources during construction of roads, a transmission line, and the Sample Management Facility. Casual observers might see or be attracted to the presence of workers, vehicles, and the generation of dust and vehicle exhaust. As Section 4.1.10 notes, the crest road would not be visible from offsite locations.

DOE would reclaim disturbed areas once construction was complete. Considering the effect of best management practices for construction projects, construction activities would be noticeable but would not dominate the attention of the viewer. Therefore, there would be small project-related visual impacts during construction.

4.3.2.11 Utilities, Energy, Materials, and Site Services

Section 4.1.11 discusses impacts to residential water, energy, materials, and site services from the Proposed Action. In all aspects, the impacts from the infrastructure improvements would be smaller than those under the Proposed Action because the scope of the activities would be smaller.

Section 4.3.2.3.3 discusses water demand for the proposed infrastructure improvements. The electricity demand for construction would be between 1.2 to 1.9 megawatts per year, which would be well within the supply capacity in the southern Nevada region (Chapter 3, Section 3.11.1). Nevada Power Company, which supplies electricity to southern Nevada, sold 21 million megawatt-hours in 2005. Construction would consume a variety of fossil fuels that included gasoline, heating oil, diesel fuel, propane, and kerosene. Overall, impacts on the regional supply of fossil fuels would be small. The fossil-fuel system in the State of Nevada has sufficient capacity to meet normal Nevada demands.

Impacts to existing emergency services, law enforcement, fire protection, and medical services at Yucca Mountain would be negligible because construction would not involve a substantial increase in the number of workers.

4.3.2.12 Management of Repository-Generated Waste and Hazardous Materials

Section 4.1.12 describes quantities of waste the Proposed Action would generate. Wastes from construction of a four-lane access road and two transmission lines would be greater than the wastes for a two-lane access road and one transmission line. Estimates of generated waste for the Proposed Action include the debris from dismantlement of the temporary structures at the North Portal and the existing Sample Management Facility at the Field Operations Center.

The proposed infrastructure improvements would generate increased volumes of nonhazardous solid waste, construction debris, hazardous waste, recyclables, sanitary sewage, and wastewater, but the additions would be small in comparison to waste generation for the Proposed Action. Chapter 3, Section 3.1.12.1 provides landfill capacities within Nevada.

4.3.2.13 Environmental Justice

Section 4.1.13 describes the analysis of environmental justice in terms of the potential for disproportionately high and adverse impacts to minority or low-income populations. Based on this information and reviews of U.S. Census information, the infrastructure improvements would not result in high impacts to any member of the public. DOE has not identified any unique exposure pathways, sensitivities, or cultural practices that could result in disproportionately high and adverse impacts to minority or low-income populations. Therefore, there would be no environmental justice impacts from these improvements.

4.3.3 BEST MANAGEMENT PRACTICES AND MITIGATION MEASURES

The Department would implement a variety of environmental protection measures and best management practices for the infrastructure improvements to avoid or mitigate potential adverse effects. Table 4-39 summarizes these measures and practices for each resource area.

4.3.3.1 Unavoidable Adverse Impacts

With the successful implementation of the best management practices and mitigation measures, unavoidable adverse impacts would be small. The small impacts would occur to fossil fuels, building materials, and land disturbance.

4.3.4 CUMULATIVE IMPACTS

A cumulative impact is an impact on the environment that results from the incremental impact of the action when it is added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Chapter 8 provides more detail on cumulative impacts for the actions in the following sections.

4.3.4.1 Land Withdrawal To Study a Corridor for a Proposed Rail Line to Yucca Mountain

On December 28, 2005, acting on an application from DOE, the Secretary of the Interior published Public Land Order No. 7653 that withdrew for 10 years about 1,250 square kilometers (310,000 acres) of public land around the potential rail lines under study from the staking of new mining claims (70 FR 76854). The withdrawal does not result in any surface disturbances, and it does not affect the development of existing valid mining claims. It does, however, preclude the staking of new claims on these public lands, which include lands in the vicinity of Yucca Mountain. Those lands are west of the area that infrastructure improvements would affect and are a subset of the broader analyzed land withdrawal area for the repository. This action would not result in cumulative impacts.

On January 10, 2007, the Bureau of Land Management announced that DOE had filed an application to request a second land withdrawal (72 FR 1235). The application is for an additional 842 square kilometers (208,000 acres) from surface entry and mining to December 27, 2015.

4.3.4.2 Activities on the Nevada Test and Training Range

The U.S. Air Force operates the Nevada Test and Training Range. The *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all) addressed potential environmental impacts of extending the land withdrawal for military activities by the Air Force. The land withdrawal renewal for the Range was approved, and activities on the Range have continued to evolve with changing military needs. In general, however, current and future developments at the Range would have small cumulative impacts with the proposed infrastructure improvements because the impacts would not occur on those Air Force lands that DOE uses for operations at Yucca Mountain.

Table 4-39. Best management practices and mitigation measures.

Resource	Practices and measures
Land use	The Department would consult with and obtain right-of-way from the Bureau of Land Management for activities on public land. DOE would follow the mitigation measures and stipulations.
	DOE would coordinate with Nye County in relation to the construction schedule and possible conflicts with any off-road vehicle events on public lands in the affected area.
Air quality	DOE would consult with the Nevada Bureau of Air Pollution Control about the possible need to modify the current air quality operating permit for operations. Stipulations in the permit would minimize impacts to air quality.
Hydrology	DOE would obtain a Construction Storm Water Permit from the Nevada Division of Environmental Protection that would include preparation of a Storm Water Pollution Prevention Plan. This plan would include established best management practices for the control of erosion and pollution while constructing crossings and working in dry washes.
	DOE would, as necessary, obtain a Section 404 permit from the U.S. Army Corps of Engineers for construction in washes that meet the Corps' criteria as jurisdictional waters of the United States and would implement mitigation measures and best management practices in the permit.
Biological resources	
Wildlife	If construction occurred during migratory bird- nesting season, a qualified biologist would survey areas before the start of construction. If the survey found active nests, DOE would delineate a buffer zone around nests, within which disturbance would not occur until the young birds fledged. The size of the protective buffer would depend on species-specific requirements.
Vegetation	Where appropriate, DOE would restore areas affected by grading, plowing, or trenching to their approximate original contours in accordance with the *Reclamation Implementation Plan* for Yucca Mountain (DIRS 154386-YMP 2001, all).
Special-status species	DOE would follow the mitigation measures for the protection of desert tortoises required by the U.S. Fish and Wildlife Service's 2001 biological opinion on Yucca Mountain (DIRS 155970-DOE 2002, Appendix O).
	DOE would clearly mark populations of special-status plant or animal species discovered during preconstruction surveys with flagging or caution tape and would require construction contractors to inform crews about the importance of avoiding flagged areas.
Cultural resources	DOE would conduct preconstruction surveys to identify cultural sites in the potentially affected areas. Each site would be evaluated for eligibility for inclusion in the *National Register of Historic Places*. Where practicable, DOE would avoid sites or, if not practicable, would collect artifacts at eligible sites in accordance with Section 106 of the *National Historic Preservation Act* and document the findings.
Occupational and public health and safety	If engineering controls were unable to maintain safe concentrations of silica dust during possible use of the excavated rock storage pile near the North Portal for road construction and surface leveling, DOE would use respiratory protection (air filters, or personal protective gear) until engineering controls could reestablish safe conditions.
Noise	DOE would only conduct construction activities during daylight hours.
Aesthetics	DOE would use shielded or down-directed lighting at the central operations area and at other new facilities at Yucca Mountain to minimize the amount of night lighting visible from offsite locations.
Environmental justice	None. However, through the ongoing Native American Interaction Program, DOE would continue to solicit input from the 17 tribes and organizations that have cultural and historic ties to the Yucca Mountain area. Through this program, the tribes and organizations can express their views and concerns about the management of cultural resources and related issues.

4.3.4.3 Nevada Test Site Activities

The Nevada Test Site has been the nation's proving ground for the development and testing of nuclear weapons. From 1951 to 1992, DOE and its predecessor agencies conducted more than 900 tests at the site. Current activities at the Test Site include the management of radioactive and hazardous wastes; weapons stockpile, stewardship, and management; materials disposition; nuclear emergency response; and nondefense research and development. Past and present activities, specifically within Area 25 where many of the facilities for the Yucca Mountain Project are, would be part of the affected environment. Current and future Test Site activities in Area 25 that could have cumulative impacts with the infrastructure improvements include the continued withdrawal of groundwater for Test Site operations.

The small incremental cumulative impacts would include land disturbance, water use, waste generation, noise, and emissions from construction equipment and fugitive dust. The impacts would be temporary.

4.3.4.4 Yucca Mountain Project Gateway Area Concept Plan

Nye County has prepared a Yucca Mountain Gateway Area Concept Plan with proposed land use designations for the area around the proposed Yucca Mountain repository entrance. Chapter 8 of this Repository SEIS contains Nye County's perspective on cumulative impacts and discusses the role of the land use concept plan as guidance for the management of development near the entrance area. Nye County proposed this plan to ensure land development would occur in an orderly manner while increasing the opportunities for industrial and commercial development. Nye County views this plan as a starting point for development of the infrastructure, institutional capacity, and facilities that would be consistent with the proposed repository land use.

There are no specific proposals for development, but incremental cumulative impacts could include additional disturbed land, water use, emissions from construction equipment, fugitive dust, waste generation, and noise.

4.3.4.5 Desert Space and Science Museum

Nye County proposes to construct a Desert Space and Science Museum and commercial facilities in the area of the Gateway Area Concept Plan. Under the proposal, the Bureau of Land Management would transfer 3.3 square kilometers (820 acres) to Nye County, of which 0.4 square kilometer (100 acres) would have permanent, developed facilities. Nye County would manage the remaining 2.9 square kilometers (720 acres) for natural resource and habitat values.

The museum would result in some additional water use and employment that could affect the regional economy. Other incremental cumulative impacts would occur only during infrastructure construction and would include emissions from construction equipment, fugitive dust, and noise.

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5

Environmental Impacts of Postclosure Repository Performance

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5. ENVIRONMENTAL IMPACTS OF POSTCLOSURE REPOSITORY PERFORMANCE

This chapter presents the approach and analyses of potential human health *impacts* from releases of *radioactive* and nonradioactive materials to the *environment* after *closure* of the proposed *repository* at Yucca Mountain. In addition, it discusses estimates of potential biological and environmental impacts from radiological and chemical *groundwater contamination*, and potential biological impacts from the *postclosure* production of heat due to *decay* of the radioactive materials that the U.S. Department of Energy (DOE or the Department) would dispose of in the repository. This chapter of the *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) summarizes, incorporates by reference, and updates the information in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS).

Waste packages would be disposed of in dedicated emplacement drifts, supported on emplacement pallets, and aligned end-to-end on the drift floor (Chapter 2, Section 2.1.2.2.2, Figure 2-8).

Closure of a repository would include the following activities (Chapter 2, Section 2.1.6):

- Emplacement of the drip shields over the waste packages;
- Backfilling of subsurface ramps and sealing of subsurface to surface openings;
- Removal of surface facilities; and
- Creation of *institutional controls*, which would include land records and surface monuments, to identify the location of the repository and discourage human intrusion.

WASTE PACKAGE

A *waste* package would consist of the corrosion-resistant outer container, the waste form and any internal containers (such as the TAD canister), spacing structure or baskets, and shielding integral to the container. The waste package would be ready for emplacement in the repository when the outer lid welds were complete and accepted.

After closure, there would be no changes in land use, no significant employment of workers, no significant water use, no change in water quality other than those from the transport of *radionuclides*, and no use of energy or other resources or generation or handling of waste. Therefore, there would be no additional impacts to land use, noise, socioeconomics, cultural resources, aesthetics, utilities, or services after closure as a result of the disposal of radioactive materials in the repository. Chapter 4 discusses impacts from construction, *operations*, *monitoring*, and closure.

DOE assessed the processes by which radionuclides could be released from a repository at Yucca Mountain and transported to the environment. The analysis used computer programs to assess the release and movement of radionuclides and hazardous materials in the environment. Some of the programs analyzed the behavior of engineered components such as the waste package, while others analyzed natural processes such as the movement of groundwater. DOE based the programs on the best available *geologic*, geochemical, and hydrologic data and current knowledge of the behavior of the materials DOE proposes for the system. The analysis used data from Yucca Mountain *site characterization* activities, material tests, and expert judgment as input parameters to estimate human health impacts. Many parameters that DOE used in the analysis cannot be exactly measured or known; therefore, DOE used a range of values. The analysis accounted for this type of uncertainty; the results are ranges of potential health impacts.

The analysis considered human health impacts during the first 10,000 years after repository closure and the radiation dose during the period from 10,000 years after closure to 1 million years after closure (the post-10,000-year period). Estimates of potential human health impacts included the effects on repository performance of such expected processes as *corrosion* of waste packages, degradation and dissolution of waste forms, flow through the saturated and unsaturated zones, and changing climate, in addition to early waste package and *drip shield* failure (a failure that could occur soon after closure due to defects in a waste package or drip shield) mechanisms and igneous and *seismic* events. Additional analyses examined the effects of such disturbances as inadvertent drilling and potential for criticality.

WHY 10,000 YEARS AND 1 MILLION YEARS?

The TSPA-SEIS model provides estimates of potential radiological impacts (doses) for two periods: the estimated dose at times for the first 10,000 years after closure and a dose at times after the first 10,000 years up to 1 million years after closure. The TSPA-SEIS model assessed annual individual doses in each of these periods.

DOE could have performed the analyses for this Repository SEIS for any number of periods. So why these two? The main reason is that EPA and NRC have proposed dose limits for a maximum annual individual dose in each period. While these dose limits will provide a regulatory limit against which NRC could evaluate DOE's application for construction authorization, they also provide a context in which to consider the potential environmental impacts of the Proposed Action.

The analysis of postclosure repository performance and environmental impacts considered two transport pathways—groundwater and the atmosphere—through which radionuclides from *spent nuclear fuel*, high-level radioactive waste, and hazardous or *carcinogenic* chemicals could reach human populations and result in impacts to public health. The principal *exposure pathway* would be groundwater. Rainwater could migrate down through the *unsaturated zone* into the repository, could dissolve or mobilize some of the material in the repository, and could carry *contaminants* from the dissolved material down through the unsaturated and saturated groundwater zones to locations where human *exposure* could occur. An atmospheric pathway could result from a volcanic conduit that intersected the repository, destroyed waste packages, and erupted at the surface. The volcanic eruption at the ground surface could disperse volcanic tephra (solid material of all sizes explosively ejected from a volcano into the atmosphere) and entrained radionuclides (radionuclides that were bound to or captured by the volcanic tephra) under atmospheric conditions. The calculation of annual *radiation dose* included human health impacts from this latter pathway (Section 5.5).

Another atmospheric pathway could result from the escape of gaseous radionuclides, such as carbon-14,

HYDROGEOLOGIC TERMS

Unsaturated zone: The region between the surface and the water table where water fills only some of the spaces (fractures and rock pores).

Matrix: The solid, but porous, portion of the rock.

Saturated zone: The region below the water table where water completely fills all spaces (fractures and rock pores).

from the repository to the surface and their downwind transport. DOE analyzed these possible airborne releases in the Yucca Mountain FEIS. Section 5.6 provides a summary of this analysis. Because DOE is not aware of significant new information or circumstances that bear on this analysis, DOE would not expect any change in the estimated impacts from the escape of gaseous radionuclides; therefore, DOE did not conduct a new analysis for this Repository SEIS.

10 CFR PART 63 and 40 CFR PART 197

In 2001, both EPA and NRC adopted public health and safety standards for any radioactive material to be disposed of in a Yucca Mountain repository. In 2004, in response to legal challenges, the U.S. Court of Appeals for the District of Columbia Circuit struck down the portions of those standards that addressed the period of time for which compliance must be demonstrated and remanded the provisions to the federal agencies for revision.

In 2005, EPA proposed new standards to address the court's decision. The proposed standards incorporate multiple compliance criteria applicable at different times for protection of individuals, the environment, and in circumstances involving human intrusion into the repository. The proposals also identify certain specific processes that must be considered in projecting repository performance. When finalized, these standards will be codified in 40 CFR Part 197, Subpart B.

Because Section 801 of the *Energy Policy Act of 1992* requires NRC to modify its technical requirements for licensing of a Yucca Mountain repository to be consistent with the standards promulgated by EPA, NRC also proposed new standards in 2005 to implement the proposed EPA standards for doses that could occur after 10,000 years but within the period of geologic stability. The proposed NRC standards also specify a value to be used to represent climate change after 10,000 years, as required by EPA, and specify that calculations of radiation doses for workers use the same weighting factors that EPA proposed for calculating individual doses to members of the public. When finalized, these standards will be codified in 10 CFR Part 63.

In developing the TSPA-SEIS model for the analysis in this Repository SEIS, DOE took into consideration the regulatory requirements in the proposed EPA and NRC standards to provide a perspective on potential radiological impacts during the postclosure period. The TSPA-SEIS model for the analyses in this Repository SEIS is in the process of being finalized for purposes of the compliance assessment to be included in the application DOE intends to file with NRC for construction authorization for a Yucca Mountain repository.

The analysis for this Repository SEIS estimated potential human health impacts from the groundwater and atmospheric transport pathways at the location of the *reasonably maximally exposed individual* (RMEI; 40 CFR 197.21), which is approximately 18 kilometers (11 miles) downgradient from the proposed repository. A hypothetical "reasonably maximally exposed individual (RMEI)" is defined with parameters that significantly affect exposure estimates set at high values so that the hypothetical individual is "reasonably maximally exposed" for the purpose of assessing potential doses that could result from releases of radioactivity from a repository. These impacts represent both radiological doses and probabilities of resultant *latent cancer fatalities*. A latent cancer fatality is a death that results from *cancer* from exposure to *ionizing radiation* or other *carcinogens*.

DOE has made modifications to the repository design and operational plans since the completion of the Yucca Mountain FEIS. DOE has modified the Total System Performance Assessment (TSPA) model to account for these changes, as well as additional data it has collected since the completion of the FEIS. Section 5.1 summarizes modifications that this Repository SEIS addresses in the TSPA model. For this

SEIS, DOE based the analyses on the TSPA model that, when finalized, will serve as the basis for the compliance assessment to be included in DOE's application to the U.S. Nuclear Regulatory Commission (NRC) for construction authorization. The references cited in Appendix F, Section F.2 of this Repository SEIS provide further details.

> **WHO AND WHERE IS THE "RMEI"?**
>
> A hypothetical "reasonably maximally exposed individual (RMEI)" is defined for the purpose of assessing potential doses that could result from releases of radioactivity from a repository .
>
> Under applicable regulations, the RMEI is located 18 kilometers (11 miles) from the repository.

Section 5.2 describes the inventory of materials that the postclosure performance assessment analyzed for potential releases from the repository; Section 5.3 provides an overview of the repository system; Section 5.4 discusses the locations for impact estimates; Section 5.5 provides the analysis of the postclosure performance for radiological impacts; Section 5.6 provides the analysis of atmospheric radiological materials in the repository; Section 5.7 describes impacts from chemically toxic materials; Section 5.8 describes the human intrusion calculations; Section 5.9 describes the evaluation of the potential for nuclear criticality in the repository and surrounding rock; Section 5.10 presents the impacts to biological resources and soils; and Section 5.11 summarizes the postclosure analyses.

5.1 Differences Between FEIS and SEIS Assessments of Postclosure Repository Performance

There are several differences between the assessments of postclosure repository performance for this Repository SEIS and those in the Yucca Mountain FEIS that accompanied the Secretary of Energy's recommendation to approve the Yucca Mountain site in 2002. Figure 5-1 shows the relationships between TSPA models and the FEIS and this SEIS. The major differences are summarized in this section.

5.1.1 RADIOLOGICAL IMPACTS

The results of assessments of postclosure repository performance for this Repository SEIS and those of the Yucca Mountain FEIS are different. The differences are due to EPA's proposed standards to avoid speculation in the post-10,000-year projection, as well as incorporation of additional data and enhancements in the description of engineered and natural components. The Yucca Mountain FEIS results included contributions from the Nominal Scenario Class, limited contributions from the Seismic Scenario Class, and contributions from Early Waste Package Failure. Igneous Scenario Class impacts were not included in the calculation of total impacts. The projections of radiological impacts in the TSPA for the SEIS include contributions from a Seismic Scenario Class, Igneous Scenario Class, Drip Shield Early Failure, Waste Package Early Failure, and the Nominal Scenario Class. As a result of these changes, several qualitative observations can be made about the FEIS results.

- The FEIS described future climates in terms of discrete alternating climate states with a precise timing of climate change. The spikes in the dose curves shown in the FEIS (for example, FEIS, page 5-26, Figure 5.4) result from imposed climate changes at fixed times and assumed percolation fluxes. These spikes are responsible for the maximum levels of the individual dose. The proposed EPA standards require DOE to represent long-term climate using a probabilistic distribution for a constant-

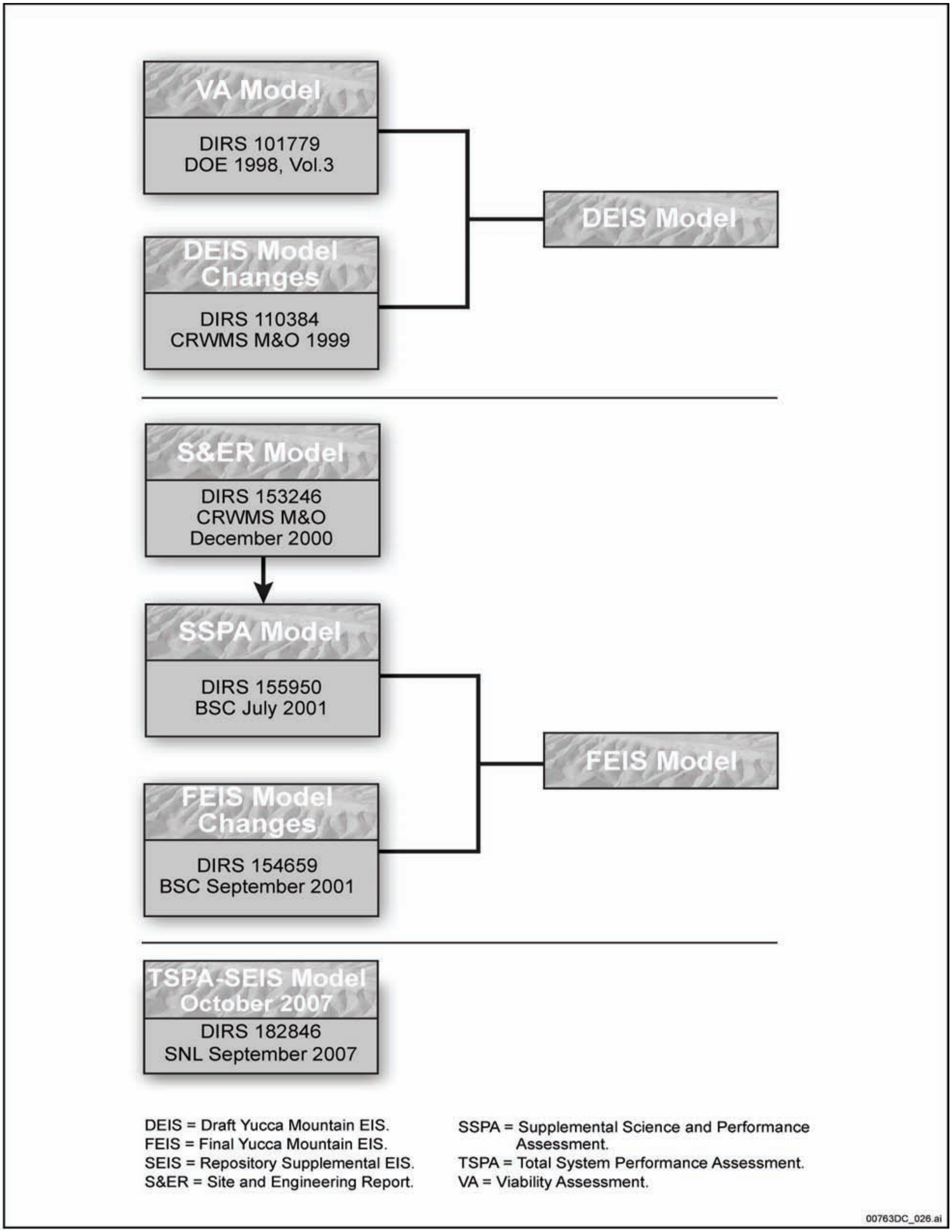

Figure 5-1. Relationship between the published TSPA models and models used for the Draft Yucca Mountain EIS, Yucca Mountain FEIS, and this Repository SEIS.

in-time but uncertain long-term average climate for Yucca Mountain specified by NRC. Inclusion of these changes in the FEIS would have resulted in a significant lowering of the projected dose values.

- The proposed EPA standards require DOE to use revised International Commission on Radiation Protection weighting factors for calculation of individual doses. In general, biosphere dose conversion factors for actinides are lower, whereas biosphere dose conversion factors for fission products are higher. Actinides were the dominant contributors to dose in the FEIS. Notably, the biosphere dose conversion factors for neptunium, which was the dominant nuclide contributing to doses in the FEIS, decreased by approximately 80 percent from the FEIS to the SEIS with the Commission's revisions. Sensitivity studies referenced in the FEIS (FEIS, page 5-31) indicate that dose estimates would be significantly lower if the revised methods were applied.

- Waste package and drip shield lifetimes are longer in the SEIS. The increase in waste package lifetimes is due in part to the increase in thickness of the Alloy-22 outer barrier to accommodate the TAD canister. Inclusion of temperature dependence of Alloy-22 corrosion rates in the SEIS results in substantially longer waste package lifetimes in the Nominal Scenario Class. Inclusion of new titanium corrosion data in the SEIS resulted in lower corrosion rates, reduced uncertainty, and longer drip shield lifetimes. Inclusion of these enhanced models in the FEIS would have resulted in a significant lowering of the projected dose values.

- For the Yucca Mountain FEIS, there was no explicit requirement for comparison to a compliance standard; the applicable NRC regulation at that time required DOE to calculate the annual dose to the RMEI if one would occur after 10,000 years after disposal but within the period of geologic stability. No regulatory standard applied to the results of this analysis nor did the regulations specify requirements for the estimate of repository performance. DOE was to include the results and their bases in the FEIS as an indicator of long-term disposal system performance.

- The regulatory standards require that DOE's projection of postclosure radiological impacts to the RMEI include those scenario classes (future states of the repository) that resulted from the features, events, and processes screening process (Appendix F, Section F.2.1). Therefore, the TSPA-SEIS projections of radiological impacts to the RMEI include contributions from a Seismic Scenario Class, Igneous Scenario Class, Early Failure Scenario Class (Drip Shield Early Failure and Waste Package Early Failure), and the Nominal Scenario Class.

The proposed EPA and NRC standards identify specific processes, such as degradation of the engineered barrier system due to general corrosion and seismic and igneous events, to be included in the postclosure performance projection and guide the development of the quantitative approach that DOE uses to avoid speculation in the post-10,000-year projection. As a result, DOE has made several changes to the TSPA model since completion of the Yucca Mountain FEIS. DOE has made other refinements to the TSPA model to improve the treatment of uncertainties, incorporate new data and understanding of processes, and reduce conservatism in the projection of repository performance (Table 5-1 contains further detail). The following factors, in addition to those above, are responsible for the major differences in projected repository performance between the Yucca Mountain FEIS and the Repository SEIS.

Table 5-1. Important changes to the TSPA since completion of the Yucca Mountain FEIS.

Component	Change	Estimated effect
Unsaturated zone flow	• Stronger basis for models - Evaluation of fast flow and transport of chlorine-36 - Justification of parameter sets used to model future climates - Evaluation of flow and transport sensitivity to hydrologic parameters	Neutral
	• Revised infiltration model and broader range of infiltration maps	Neutral
	• Revised calibration method to develop probability weights for infiltration maps	Neutral
	• NRC specified percolation flux for post 10,000-year period per proposed rule	Decrease in dose after 10,000-years
	• Basis on enhanced treatment of uncertainties in input parameters	Neutral
Engineered barrier system environment—thermal hydrology and in-drift chemistry	• Thermal hydrology - Improved basis for model validation - In-drift condensation processes included	Neutral
	• Near-field/in-drift chemistry - Reevaluated data to constrain in situ water chemistry - Improved model to represent composition of seepage entering emplacement drifts	Small decrease in dose
Abstraction of waste package and drip shield degradation	• Waste package outer barrier corrosion	
	- Additional data available	Supports model basis
	- Thermal dependency of general corrosion included	Large decrease in dose
	- Localized corrosion due to seepage included	Small increase in dose
	• Waste package outer barrier stress corrosion cracking - Improved stress/stress intensity factor profiles	Neutral
	• Drip shield early failure included	Small increase in dose
	• Additional drip shield general corrosion data available	Decrease in dose
Source term	• No credit taken for the ability of cladding to prevent or reduce degradation of commercial spent nuclear fuel	Increase in dose
	• Broader range of in-package chemistry conditions and resulting impacts on waste form degradation considered	Small decrease in dose
Engineered barrier system radionuclide transport	• Improved representation of radionuclide transport through the waste package	Small decrease in dose
	• Improved representation of radionuclide mass release to fracture and matrix portions of the host rock under the engineered barrier system	Small decrease in dose
	• Representation of kinetic sorption of plutonium and americium on iron oxyhydroxide colloids and stationary corrosion products in the waste package	Small decrease in dose
	• Sorption on TAD canister corrosion products included	Small decrease in dose
Unsaturated zone radionuclide transport	• Transport model revised to reflect transport in a dual-continuum fracture/matrix system more accurately	Small decrease in dose
	• Updated analyses of sorption and diffusion parameters	Neutral

Table 5-1. Important changes to the TSPA since completion of the Yucca Mountain FEIS (continued).

Component	Change	Estimated effect
Saturated zone flow and transport	• Updated hydrogeologic framework model that incorporates new Nye County drilling data and updated USGS regional model	Neutral
	• Updated and recalibrated site-scale saturated zone flow model - Water-level measurements in new Nye County wells - New hydrochemical data in flow model validation analysis	Neutral
	• Updated saturated zone flow and transport abstraction model - Reevaluation of parameter uncertainty distributions in consideration of new information	Small decrease in dose
Biosphere	• Incorporation of additional pathways	Increase in dose
	• Inclusion of dosimetric inputs consistent with ICRP Publication 72 and based on the concepts recommended in ICRP Publication 60	Decrease in dose
	• Uncertainty in biosphere dose conversion factors included	Neutral
	• GoldSim-based model (GENII-S used in Yucca Mountain FEIS)	Neutral
Seismic scenario class	• Inclusion of the seismic scenario class	Increase in dose
	• Detailed damage analyses developed for degraded states of the engineered barrier system components including the TAD-bearing waste packages	Increase in dose
Igneous scenario class	• Assume all drip shields and waste packages destroyed by magma intrusion	Increase in dose
	• New parameter values based on analogue data - Dike length, width, and orientation and number of dikes - Conduit size and number and locations of conduits - Fraction of eruptive material in tephra, cone, and lavas	Neutral
Treatment of uncertainty and variability	• Improved guidelines and management controls for characterization of uncertainty consistently across component abstractions	Consistent treatment of uncertainty
	• Epistemic and aleatory uncertainty separated in the TSPA analyses	Consistent treatment of uncertainty
Features, events, and processes analysis	• Screening justifications updated and revised based on new technical information available since DOE published the TSPA for the Site Recommendation[a] (e.g., TAD canisters; seismic impacts; localized corrosion)	Improve defensibility of included scenario classes
TSPA model development and implementation	• Technical basis for TSPA planned for the license application builds on the technical foundation documented for the TSPA for the Site Recommendation and updates[b] for the FEIS	Improve defensibility
	• Additional confidence building (validation)	Improve defensibility
	• Additional rigor added to configuration and control processes	Improve defensibility

a. DIRS 153246-CRWMS M&O 2000, all.

b. DIRS 155950-BSC 2001, all; the Yucca Mountain FEIS referred to this model as the "Supplemental Seismic and Performance Analyses" model.

TAD = Transportation, aging, and disposal (canister).

USGS = U.S. Geological Survey.

5.1.1.1 Drip Shield and Waste Package Corrosion

For this Repository SEIS, DOE included new Titanium Grade 7 corrosion data that were based on 2.5-year tests, which resulted in reduced uncertainty in corrosion rates, lower corrosion rates, and longer drip shield lifetimes. In the Yucca Mountain FEIS, drips shields did not start failing until approximately 20,000 years after emplacement and most of the drip shields failed by about 40,000 years. In the SEIS, drip shields did not start failing until approximately 260,000 years and most of the drip shields failed by 310,000 years.

DOE included temperature dependence of Alloy-22 corrosion rates for this Repository SEIS, which led to substantially longer waste package lifetimes in the Nominal Scenario Class. The following discussion summarizes waste package performance in the Nominal Scenario Class for the Yucca Mountain FEIS and the repository SEIS. In the Yucca Mountain FEIS, the mean waste package failure behavior resulted in waste package failure from stress corrosion cracking beginning around 15,000 years, and about 50 percent of the waste packages failed by stress corrosion cracking and general corrosion by 100,000 years. For this Repository SEIS, the waste package failure initiated by stress corrosion cracking is estimated to begin around 100,000 years and about 60 percent of the waste packages are estimated to fail by stress corrosion cracking by 1 million years. General corrosion failures are estimated to start at around 400,000 years and about 10 percent of the waste packages could experience a general corrosion breach within 1 million years. The increase in waste package lifetimes was also due in part to the increase in thickness of the Alloy 22 outer barrier for the commercial spent nuclear fuel waste packages from 20 millimeters (0.79 inch) in the FEIS to 25 millimeters (0.98 inch) in this SEIS to accommodate the TAD canister.

5.1.1.2 Seismic Scenario Class

The TSPA-SEIS implemented damage models to simulate the response of drip shields, codisposal waste packages, and TAD canisters with commercial spent nuclear fuel waste packages to vibratory ground motion, drift collapse, and fault displacement.

5.1.1.3 Igneous Scenario Class

TSPA-SEIS assumed all drip shields and waste packages in the repository would be destroyed if a basaltic dike intersects and magma intrudes into one or more emplacement drifts. That is, all drip shields and waste packages in the repository would lose their ability to limit or prevent the flow of water and the movement of radionuclides.

5.1.1.4 Impacts at Different Locations

In the FEIS the results for RMEI, located at 18 kilometers (11 miles) were scaled to two other distances: 30 kilometers (19 miles) and 60 kilometers (37 miles). The scaling was done using scale factors developed from separate modeling for transport in the alluvium of Amargosa Valley. This separate modeling used a simple, dispersion only model that did not account for any sorption or other attenuating phenomena other than hydrodynamic dispersion (spreading) of the radionuclide plume. New modeling since the FEIS indicates a considerably smaller plume width. Upon review of basis for dose calculations DOE confirmed that if the plume were diluted into the 3.7 million cubic meters (3000 acre-feet) water use at the RMEI location, this large water use would likewise consume the entire plume at all other locations. This is because the spreading of the plume would be insufficient for any of the radionuclides to escape capture in the water-use volume. Furthermore, the time-delay from further transport in the alluvium would give insignificant amounts of decay. Therefore, the estimated doses at all locations would be the same. Thus, doses at distances other than the RMEI location are not calculated in this SEIS. It was further recognized that it is not realistic to apply the lifestyle of the RMEI to the entire population of the region surrounding the proposed repository since a large percentage of the population is urban with lifestyles dissimilar to the RMEI. Therefore, no basis exists for assessing population dose. Furthermore, there is no need or requirement to report population dose as an impact. Thus, population dose is not assessed in this Repository SEIS.

5.1.2 IMPACTS FROM TOXIC CHEMICALS

Since the FEIS, there has been a change in how chromium chemistry is treated both in the Engineered Barrier System (emplacement drift) environment and the in-package environment. In the FEIS it was conservatively assumed that when placed in solution, chromium would fully oxidize to the +6 valence state, chromium(VI). Additional research and analysis has shown that this is an unrealistic assumption for the chemical environments of the Engineered Barrier System and the internal of the waste package. There is very strong evidence that most or all of the chromium, dissolved from construction materials such as stainless steel and Alloy-22, will exist in the +3 valence state, chromium(III). Two important distinctions between these two valence states is that chromium(VI) is highly soluble in water and is considered toxic to humans while chromium(III) is highly insoluble (on the order of less than 1×10^{-3} milligrams/liter) and is considered nontoxic to humans. Based on these new findings, chromium was eliminated from further consideration in this Repository SEIS when evaluating impacts from chemically toxic substances (see Appendix F, Section F.5.1).

5.2 Inventory for Performance Calculations

This postclosure analysis identified the inventory by the source category of waste material to be disposed of (*commercial spent nuclear fuel*, *DOE spent nuclear fuel*, surplus weapons-usable plutonium, and high-level radioactive waste). For modeling purposes, the analysis averaged the inventory for each of the categories into an appropriate number of packages, each with identical contents. The modeled inventories consisted of two basic types of waste packages: a commercial spent nuclear fuel waste package and a codisposal waste package that would contain DOE spent nuclear fuel and high-level radioactive waste *canisters*.

5.2.1 INVENTORY OF RADIOACTIVE MATERIALS

There are more than 200 radionuclides in the analyzed waste inventory. The analysis for this Repository SEIS used a subset of the 200 radionuclides. The number of radionuclides to be analyzed was determined by a screening analysis. It would be impractical for DOE to model all of these radionuclides in a TSPA, the purpose of which was to eliminate from further consideration (screen out) radionuclides that are unlikely to significantly contribute to radiation dose to the RMEI. The radionuclide screening analysis was recently revised to incorporate updated radionuclide inventory and screening factor data (DIRS 177424-SNL 2007, all). This screening analysis determined that 32 radionuclides could potentially contribute an important fraction of the dose to the RMEI. This set of radionuclides forms the basis for the analysis this chapter discusses. However, it is noted that the TSPA simulations presented in this Repository SEIS for the first 10,000-years after closure were not based on the revised version of the radionuclide screening analysis and 32 radionuclides, but on 29 important radionuclides identified in the previous version of the screening analysis (DIRS 160059-BSC 2002, all). In the revised version of the screening analysis, three additional radionuclides, chlorine-36, selenium-79, and tin-126, were screened in for postclosure analysis. Although these three additional radionuclides were not included in the assessment of postclosure repository performance for the first 10,000-years after repository closure, they were included in the post-10,000-year assessment. The exclusion of the three identified radionuclides from the analysis of the first postclosure time period did not have a significant impact to projected dose. Based on the post-10,000-year total annual dose assessment, these three radionuclides would make the following estimated contributions to total mean annual dose to the RMEI for the first 10,000 years after repository closure: 0.02 millirem (chlorine-36), 0.01 millirem (selenium-79), and 0.000001 millirem (tin-126) for a total annual mean contribution of 0.03 millirem.

The analysis abstracted the total inventory into two types of representative waste packages:

1. A commercial spent nuclear fuel package. For analysis purposes, naval spent nuclear fuel is conservatively modeled as commercial spent nuclear fuel.

2. A codisposal package with high-level radioactive waste in a glass *matrix* and DOE spent nuclear fuel.

Appendix F, Table F-3 lists the abstracted inventory for the representative waste packages.

5.2.2 INVENTORY OF CHEMICALLY TOXIC MATERIALS

DOE would use several materials in the construction of the repository that are potentially chemically toxic. The Department performed an analysis of impacts from chemically toxic materials for the 10,000-year postclosure period. During that time, only a few waste packages would be likely to fail. Therefore, the analysis did not consider any chemically toxic materials inside waste packages. For the Yucca Mountain FEIS, DOE used a screening analysis to determine which, if any, of these materials would have the potential for transport to the *accessible environment* in quantities sufficient to be toxic to humans (DIRS 155970-DOE 2002, pp. I-52 to I-54). The results of this analysis showed that the remaining chemically toxic materials of concern would be chromium, molybdenum, nickel, and vanadium. DOE performed additional screening analysis based on recent research (Appendix F, Section F.5.1). The additional analysis eliminated chromium from further concern, leaving molybdenum, nickel, and vanadium requiring further analysis. These elements would dissolve into solution as construction materials for the repository and waste packages corroded. As these elements dissolved, some portion of the material would precipitate as minerals and some would stay in solution. The quantities of these elements that remained in solution would be subject to continuous release from the repository.

Because there would be a large mass of construction materials, it would be unlikely that they would corrode completely during the first 10,000 years after closure. Therefore, DOE conservatively assumed that a constant release of material would occur for the entire period. The release rate would depend on the total surface area that was exposed to water, rather than on the total mass. The important sources of these materials would be the exposed surfaces available for corrosion. Appendix F, Section F.5.2.2 contains estimates of the amounts available for transport from these surfaces. Table 5-2 lists the total surface areas of alloys of concern and their elemental compositions.

Table 5-2. Total surface area of construction materials and their compositions.

Alloy	Total surface area (square meters)	Composition as weight percent		
		Molybdenum	Nickel	Vanadium
Stainless steel[a]	2,500,000	2.5	12	0
Alloy-22	580,000	14.5	57.2	0.35

Source: Appendix F, Section F.5.2.2.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. The analysis assumed Stainless Steel Type 316L for all stainless steel.

An important design modification since the completion of the Yucca Mountain FEIS is the addition of extensive stainless-steel ground support hardware (support sheets and rock bolts). This additional stainless steel would account for over 90 percent of the total exposed stainless steel in the proposed repository.

5.3 System Overview

DOE would emplace radioactive materials at about 300 meters (1,000 feet) beneath the surface in the proposed repository. The emplaced materials would be almost entirely in the form of solids with a very small fraction of the radioactive inventory in the form of trapped gases (Section 5.6). The primary means for the radioactive and chemically toxic materials to contact the *biosphere* would be along groundwater pathways. The materials could affect human health if the following sequence of events occurred:

- The waste packages and their contents were exposed to water either through nominal or disruptive processes.
- Radionuclides or chemically toxic materials in the package materials or wastes became dissolved or mobilized in the water.
- The radionuclides or chemically toxic materials were transported in water to an *aquifer*, and the water that carried these materials was withdrawn from the aquifer through a well or at a surface-water discharge point and used directly by humans for drinking or in the human food chain (such as through irrigation or watering livestock).

An atmospheric pathway could result from a volcanic conduit that intersected the repository, destroyed waste packages, and erupted at the surface. The eruption at the surface could disperse volcanic tephra and entrained radionuclides under atmospheric conditions. However, the probability of this event would be very low and its impacts would be extremely small (Appendix F, Section F.4.2.1.2). A second atmospheric pathway could result from gaseous radionuclides that leaked from the repository and were transported downwind. This would result in extremely small impacts (Section 5.6). Therefore, the access to and flow of contaminated water are the most important considerations in a determination of potential health effects.

5.3.1 COMPONENTS OF THE NATURAL SYSTEM

Figure 5-2 is a simplified schematic of a repository at Yucca Mountain. It shows the principal features of the natural system that could affect the postclosure performance of the repository. Yucca Mountain is in a dry, semiarid desert environment where the current average annual precipitation over the unsaturated zone

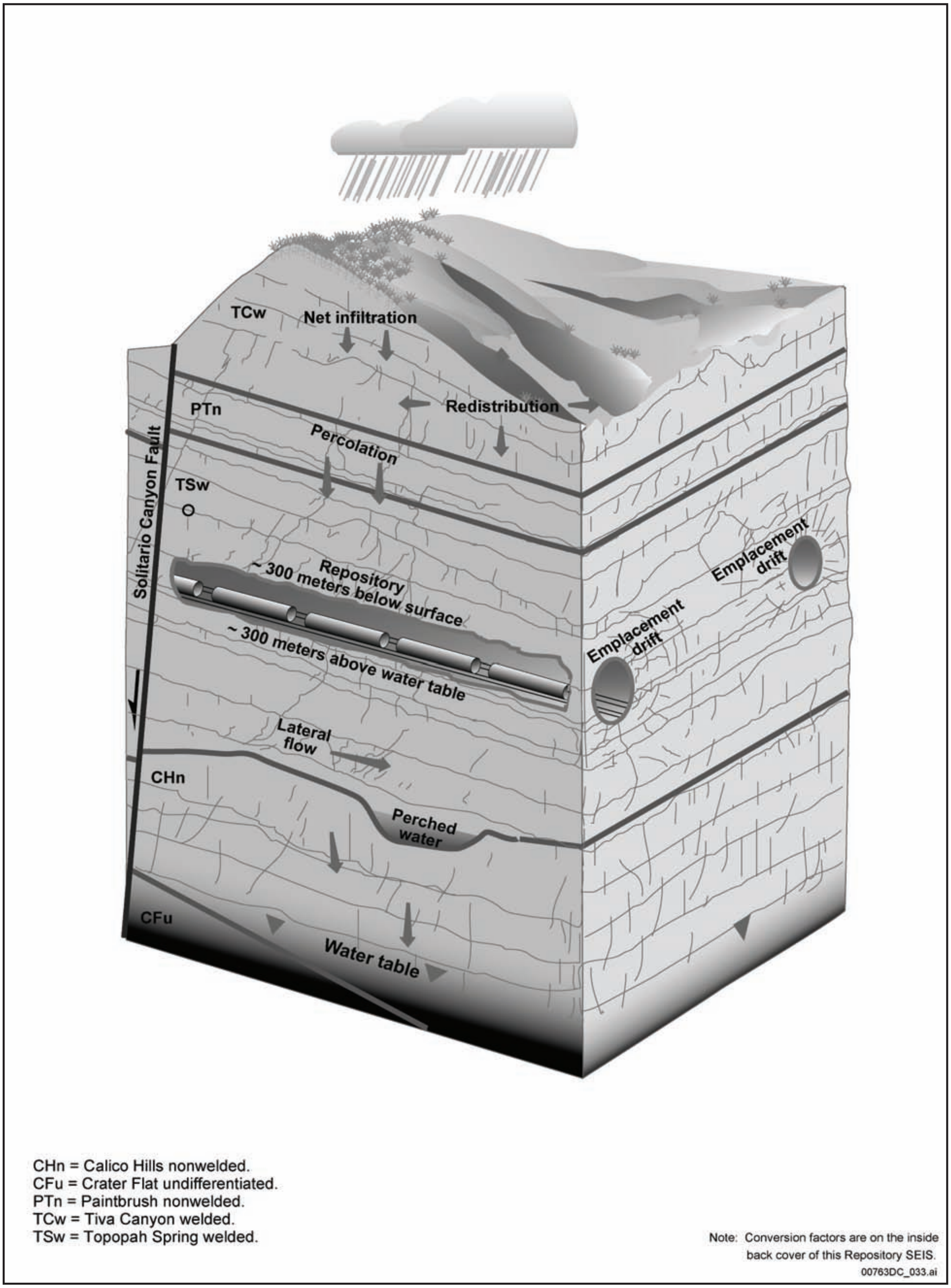

Figure 5-2. Components of the natural system.

flow and transport model area is 170 millimeters (7 inches), which varies by specific location (DIRS 174294-SNL 2007, all). The *water table* is an average of 600 meters (2,000 feet) below the surface of the mountain. The proposed repository would be in unsaturated rock approximately midway between the desert environment and the water table.

The water table is the boundary between the unsaturated zone above and *saturated zone* below. In the subsurface region above the water table, the rock contains water, but the water does not fill all the open spaces in the rock. Because the open spaces are only partially filled with water, this region is called the unsaturated zone. Water in the unsaturated zone tends to move generally downward in response to capillary action and gravity. In contrast, water fills all the open spaces in the rock below the water table, so this region is called the saturated zone. Water in the saturated zone tends to flow laterally from higher to lower pressures. Both zones contain several different rock types, as Figure 5-2 shows. The layers of major rock types in the unsaturated zone at the *Yucca Mountain site* are the Tiva Canyon welded, Paintbrush nonwelded, Topopah Spring welded, Calico Hills nonwelded, and Crater Flat undifferentiated *tuffs*. The figure shows the Solitario Canyon Fault, which forms the western boundary of the repository block. *Faults* are slip zones where seismic events have displaced rock units vertically, laterally, or diagonally, which results in discontinuous rock layers. These slip zones tend to form a thin plane in which there is more open space that acts as a channel for water. Some faults tend to fill with broken rock that forms as they slip, so they have a very different flow property from that of the surrounding rock. The proposed repository would be in the Topopah Spring *welded tuff* in the unsaturated zone, at least 300 meters (1,000 feet) below the surface and at least 300 meters above the water table.

When it rains at Yucca Mountain, most of the water runs off, is lost to evaporation, or is taken up by plants growing on the mountain. A small amount infiltrates the rock on the surface. The small amount of water that infiltrates the rock and does not evaporate percolates down through the mountain to the saturated zone. If there was a breach in the package containment, water that flowed through the unsaturated zone into the proposed repository could dissolve some of the waste material and carry it through the groundwater system to the accessible environment where exposure to humans could occur.

5.3.2 COMPONENTS OF THE WASTE PACKAGE AND DRIP SHIELD

The waste packages would consist of two concentric cylindrical containers sealed with an outer welded lid. The inner cylinder would be stainless steel. The outer cylinder would be a corrosion-resistant nickel-based alloy (Alloy-22). Alloy-22 would protect the underlying structural material (stainless steel) from corrosion, and the structural material would support the thinner corrosion-resistant material. Additionally, spent nuclear fuel and high-level radioactive waste would be in their own sealed container. Commercial spent nuclear fuel waste packages would contain a stainless-steel transportation, aging, and disposal (TAD) canister. DOE co-disposal waste packages would contain disposable canisters. The current design calls for *emplacement* of titanium drip shields over the waste packages just before repository closure. With the drip shield in place, the Alloy-22 outer cylinder would be the second corrosion *barrier* that protected the waste from contact with water. The use of two distinctly different corrosion-resistant materials would reduce the probability that a single environmental condition could cause the failure of both materials. Before the double-walled waste package was sealed, helium would be added as a fill gas. The helium would prevent corrosion of the waste form and help transfer heat from the waste form to the inner wall of the waste package prior to failure of the Alloy-22 outer cylinder. The movement of heat away from the waste form would be an important means to control waste package temperatures.

5.3.3 VISUALIZATION OF THE REPOSITORY SYSTEM FOR ANALYSIS OF POSTCLOSURE IMPACTS

In general, DOE modeled the repository system as a series of processes linked together, one after the other, spatially from top to bottom in the mountain. From a computer modeling standpoint, it is important to break the system into smaller components that relate to the information collection method. An operating repository system would be completely interconnected, and virtually no process would be independent of other processes. However, the complexity of such a system demands some idealization of the system for the performance of an analysis.

The first step in the visualization is the development of a list of all possible features, events, and processes that could apply to the behavior of the system. An example of a *feature* is the existence of a fault, an example of an *event* is a seismic event (*earthquake*), and an example of a *process* is the gradual degradation of the waste package wall by general corrosion. DOE used various types of analyses to screen the list to determine the features, events, and processes it should include in the modeling. The Department assembled the chosen features, events, and processes into scenario classes, which are descriptions of how features, events, and processes link together to result in a certain outcome (Appendix F, Section F.2.1 contains more detail on features, events, and processes).

The elements of the repository system model, referred to in this chapter as the TSPA-SEIS model, fall into the following categories, which are generally related to parts of the system:

- Unsaturated zone flow,
- *Engineered barrier* system environments,
- Waste package and drip shield degradation,
- Waste form degradation,
- Engineered barrier flow and transport,
- Unsaturated zone transport,
- Saturated zone flow and transport, and
- Biosphere.

Appendix F, Sections F.2.2 through F.2.9, discuss the individual models associated with these elements. Sections F.2.10, F.2.11, F.4.1.2, and Sections 5.8 and 5.9 discuss the following scenario classes and assessments, respectively:

- Igneous Scenario Class,
- Seismic Scenario Class,
- Early Waste Package and Drip Shield Failure Scenario Class,
- Human intrusion, and
- Nuclear criticality.

During the development of the TSPA-SEIS model, DOE had to make assumptions in addition to those mandated by regulation, primarily to account for situations for which there were limited data. If data are limited, the use of appropriate assumptions and associated conservative data values is necessary. The U.S. Environmental Protection Agency (EPA) and NRC rulemaking processes acknowledged that uncertainty about physical processes over the large space and time scales of interest will remain, even after many years of site characterization. This postclosure analysis does not seek an exact prediction but rather a cautious but reasonable projection (or forecast) of what could occur, which includes a quantitative evaluation of uncertainty in that projection.

ASSUMPTIONS

The assessment of postclosure impacts sometimes used assumptions in the formulation of models. An assumption is a premise taken as a starting point for some element of the modeling for which there usually is no absolute proof. Assumptions normally account for qualitative uncertainties (where an absolute probability cannot be assigned). There are two types of assumptions: (1) if there is a high certainty (although unquantified) that the premise will hold true and (2) if the assumption is conservative (that is, all alternative assumptions would lead to a smaller impact). A conservative assumption is often used if there is considerable uncertainty about the alternative premise that is more likely. Some assumptions are mandated by regulations that prescribe how the modeling is to occur. A set of assumptions defines the conceptual model used for the analysis. A set of alternative assumptions would represent an alternative model. DOE conducted sensitivity studies to compare alternative models to help define the importance of certain assumptions, especially if there was considerable uncertainty (Section 5.2.4.2.3).

Each assumption has a basis, which can be the reason the assumption represents a condition of high certainty, a statement that it is mandated by regulations, or a statement that it is conservative in relation to the outcome of impact analysis.

5.3.4 UNCERTAINTY

As with any impact estimate, there is a level of uncertainty, especially for the estimation of impacts over thousands of years. In this context, uncertainty is the measure of confidence in the forecast in relation to a determination of how a system will operate or respond. The amount of uncertainty in an impact estimate is a reflection of several factors, including the following:

- An understanding of the components of a system (such as human, societal, hydrogeologic, or engineered) and how those components interact.
- The time scale over which estimates are made. Longer time scales for forecasts produce greater potential for uncertainty. This is particularly true for events that might or might not occur in the future and how a system evolves in response to these future events.
- The available computation and modeling tools. Models are based on a set of working hypotheses, assumptions, and parameter values. These factors are inherently uncertain because of the complexity and variability of a natural system.

DOE recognizes that uncertainties exist from the onset of an analysis; however, forecasts are valuable in the decision making process because they provide insight based on the best information and scientific judgments available. This section discusses uncertainties in the context of possible effects on the impact estimates in this chapter.

5.3.4.1 Uncertainty in Societal Changes and Climate

The analysis this chapter presents is consistent with the regulatory requirements in the proposed EPA and NRC standards. Therefore, this analysis uses an approach that involves estimation of radiological exposure to a defined RMEI. EPA and NRC based the characteristics of the RMEI on societal conditions as they exist today and include consideration of current population distributions, groundwater use, and food consumption patterns. The proposed standards also specify a value to be used to represent climate change after 10,000 years, and specify that calculations of radiation doses for workers use the same weighting factors that the EPA proposed for calculation of individual doses to members of the public.

DOE based estimates of future climatic conditions on what is known about the past, and considered climate impacts due to human activities. Calcite in Devils Hole, a fissure in the ground about 40 kilometers (25 miles) southeast of Yucca Mountain, provides the best record of climate changes over the past 500,000 years. The record shows continual variation, often with rapid jumps, between cold glacial climates (for the *Great Basin* these are called pluvial periods) and warm interglacial climates similar to the present. The analysis assumed that the current climate is the driest it will ever be at Yucca Mountain; this is reasonable based on the climatological record that has been projected for the next 10,000 years.

5.3.4.2 Uncertainty in Models and Model Parameters

The postclosure performance model that DOE used to assess the impacts from groundwater migration includes a number of submodels, each of which must account for features of the system, likely and unlikely events, and processes that would contribute to the release and migration of materials. Because of the long periods to be simulated, the complexity and variability of the natural system, and other factors, the performance modeling must deal with uncertainty. This section discusses the nature of the uncertainties, how DOE accounted for them in this Repository SEIS, and their implications to interpretation of impact results.

5.3.4.2.1 *Relationship Between Variability and Uncertainty*

Uncertainty in model projections of repository performance comes from two major sources: (1) variability in what could happen in the future (*aleatory* uncertainty), and (2) lack of knowledge about quantities that have fixed values in the calculation of either the likelihood of future events at the proposed repository or impacts of these events (*epistemic* uncertainty). Alternative terminology includes the use of *stochastic*, *variable*, and *irreducible* as alternatives to aleatory, and the use of *subjective*, *reducible*, or *state of knowledge* as alternatives to epistemic.

Uncertainty and variability are, in general, related. The exact nature of the variability in a natural system cannot be known because all parts of the system cannot be observed. For example, DOE cannot dig up all the rock in Yucca Mountain and determine that the positioning of the rock layers is exactly as core sample data have suggested. Therefore, there is uncertainty about the properties of the rock at specific locations in the mountain because properties change with distance and it is not known how much they change at any given location. For example, if a function *f(x,y)* characterizes the two-dimensional variability of some quantity, such as thermal conductivity, there are most likely many possible values for this function of varying levels of credibility. Thus, the function *f(x,y)* characterizes spatial variability, but a lack of knowledge of how to define *f(x,y)* exactly is epistemic uncertainty. If the variability can be appropriately quantified or measured, a model usually can be developed to include this variability in addition to the uncertainty in the representation of variability. However, the ability to model some types of spatial variability can be limited not only by lack of data but also by the capacity of a computer to complete calculations (for example, if one simulation took weeks or months to complete). In these instances, variability must be simplified to be reasonable and appropriate.

The analysis used two basic tools to deal with uncertainty and variability: alternative conceptual models and probability theory. It used alternative conceptual models to examine uncertainty in the understanding of a key physical-chemical process that controls system behavior. For example, different conceptual models of how water in *fractures* interacts with water in the smaller pores or matrix of the rock in the unsaturated zone lead to different flow and transport models. Sometimes conceptual models are not mutually exclusive (for example, both matrix and fracture flow can occur), and sometimes they do not exhaustively cover all possibilities. The analysis used conservatism at the subsystem and total system levels to select the best alternative conceptual model to use rather than to propagate quantitatively multiple conceptual models through the TSPA-SEIS model.

The analysis used probability theory to understand the impacts of uncertainty in specific model parameters (that is, would results change if the parameter value was different) and to characterize how the repository system might evolve in time due to the occurrence of disruptive events. It used the *Monte Carlo sampling technique* to handle uncertainty in specific model parameters. This technique involves random Latin hypercube sampling of ranges of likely values, or *distributions*, for all uncertain input parameters. Distributions describe the probability of a particular value falling in a specific range. A common type of distribution is the familiar bell-shaped curve, known as the *normal distribution*. Many different types of distributions describe parameters in the consequence analysis that are appropriate to the understanding of the values and their probabilities. The analysis calculated many realizations of repository system behavior, each based on one set of samples of all the inputs. Each total system realization had an associated probability, so there is some perspective on the likelihood that set of circumstances would occur. The Monte Carlo method yields a range for any chosen performance measure (for example, annual individual dose in a given period at a given location) and a probability for each value in the range. In other words, it gives estimates of repository performance and determines the uncertainties in those estimates. This chapter expresses the impact estimates as the mean, median, and 95th-percentile values (that is, the value for which 95 percent of the results were smaller).

5.3.4.2.2 *Uncertainty in Data*

Some uncertainties for input parameters or models result from a lack of data. Such data gaps can be due to the status of research (perhaps with more data expected later) or conditions that restrict or prevent collection of certain data (for example, data that would require tests over impractically long periods or the necessity for minimal disturbance of the emplacement site). Uncertainty in data is a subset of parameter and model uncertainty.

The use of parameter distributions and studies of alternative models can help improve the understanding of how data uncertainty can affect the range of the impact results. Further, sensitivity studies can provide insight into the sensitivity of the model to particular parameters. Sensitivity studies identify data that are important to the modeled results, which can help identify those areas for which the study needs additional data. DOE has generated additional data since the completion of the Yucca Mountain FEIS to help improve its ability to characterize the range of impacts in this Repository SEIS. The following are examples of additional data and their uses:

- DOE has measured concentrations of chemical components in the rock, such as chloride, bromide, and sulfate, and the results have helped to identify fast paths for water flow. Ongoing analyses of the isotopic ages of fracture-lining minerals have provided additional information about the history of water movement. These studies have improved the understanding of flow paths and flow rates for water that moves through the unsaturated zone, and have revealed certain characteristics of the water, such as chemical composition and temperature. The analysis has used this new information to model the unsaturated zone more accurately (DIRS 175177-SNL 2007, all).

- DOE has investigated the effects of heat on the seepage of water into emplacement drifts in a drift-scale thermal test and laboratory experiments; these studies have provided additional data for models that predict the effects of coupled processes (DIRS 179590-SNL 2007, all).

- Accelerated corrosion testing of Alloy-22 has enabled more complete estimates of corrosion rates; DOE has used these data to improve the waste package degradation model (DIRS 178519-SNL 2007, all).

5.3.4.2.3 *Consideration of Alternative Conceptual Models*

There were three possible approaches to the incorporation of discrete alternative models in the performance analysis: (1) weighting alternative models into one comprehensive Monte Carlo simulation ("lumping"), (2) performing multiple Monte Carlo simulations for each discrete model, and (3) keeping the discrete models separate and evaluating them individually at the subsystem level to assess uncertainties and conservatisms and, through the use of expert judgment, implementing the reasonable and sometimes conservative models in the Monte Carlo simulation. The analysis used the third alternative to develop the main results in Section 5.5.

5.3.4.2.4 *Uncertainty and Postclosure Analysis*

The TSPA-SEIS analysis accounted for aleatory and epistemic uncertainties. Both aleatory and epistemic uncertainties were quantified with probability distributions that were propagated through the probabilistic Monte Carlo analysis. Using this technique, uncertainty in TSPA-SEIS projections were quantified via multiple sampling of aleatory and epistemic probability distributions and corresponding model simulations or realizations. The benefits of this probabilistic approach included: (1) obtaining a representative range of possible outcomes to quantify uncertainty of TSPA-SEIS projections, and (2) analyzing the relationship between the uncertain inputs and uncertain outputs to provide understanding of the effects of uncertainties on TSPA-SEIS projections.

5.3.4.2.5 *Uncertainty and Sensitivity*

In addition to accounting for the uncertainty, there is a need to understand characteristics of the engineered and natural systems (such as the unsaturated and saturated zones of the groundwater system) that would have the most influence on repository performance. This information helps define uncertainty in the context of what would influence results the most. This concept is called sensitivity analysis, which uses a number of methods to explain the results and quantify sensitivities. The overall postclosure performance of the repository would be a function of sensitivity (if a parameter was varied, how much would the performance measures change) and uncertainty (how much variation of a parameter would be reasonable). For example, the postclosure performance results could be sensitive to a certain parameter, but the value for the parameter is exactly known. The uncertainty analysis techniques described below would not identify that parameter as important. However, many parameters in the analyses have associated uncertainties and become highly important to performance. On the other hand, the level of their ranking can depend on the range of uncertainty.

WHY IS THE TSPA MODEL PROBABILISTIC?

The TSPA model uses statistical sampling of many parameters and generates 300 realizations (for example, "futures"), each with a unique sampling of parameter values. Such a model is known as a probabilistic model. (Other text boxes describe how this is applied to obtain results).

Many parameters are not known exactly but rather are represented as a distribution of values, with a probability assigned to each value (one well-known type of distribution is the "bell-shaped curve" or "normal" distribution). A probabilistic model is an appropriate way to produce results that reflect these parameter uncertainties.

In developing the TSPA model used for the analysis in this Repository SEIS, DOE took into consideration the regulatory requirements in the proposed EPA and NRC standards to provide a perspective on potential radiological impacts during the postclosure period.

System performance would be sensitive to the repository design, but models and parameters for these options do not have an assigned uncertainty. Therefore, although they can be important, uncertainty analysis does not identify them as key parameters. Discrete design analyses are necessary to evaluate performance for specific design features (for example, waste package thickness). The determination of the parameters or components that are most important depends on the particular performance measure. The 1993 and 1995 TSPAs (DIRS 100111-CRWMS M&O 1994, all; DIRS 100191-Wilson et al. 1994, all; DIRS 100198-CRWMS M&O 1995, all) demonstrated this point. These analyses showed, for example, that the important parameters would be different for 10,000-year doses than for post-10,000-year period doses.

There are several techniques for the analysis of uncertainties, which include the use of scatter plots where the results (for example, annual individual dose) are plotted against input parameters and visually inspected for trends. In addition, performance measures can be plotted against various subsystem outputs or surrogate performance measures (for example, waste package lifetime) to determine if that subsystem or performance surrogate would be important to performance. There are several formal mathematical techniques for evaluation of the sets of realizations from a Monte Carlo analysis to extract information about the effects of parameters. Such an analysis determined the principal factors that would affect the performance of the repository.

5.3.4.3 Uncertainty Analysis for the TSPA-SEIS

The *Total System Performance Assessment for the Draft Supplemental Environmental Impact Statement* (DIRS 182846-SNL 2007, all) documented the methodology used to develop a comprehensive quantitative analysis of the possible future behavior of a *Yucca Mountain repository*. The methodology combined detailed conceptual and numerical models of each individual and coupled process in a single *probabilistic* model for use in assessment of how a repository might perform over long periods.

DOE has always recognized that uncertainties will remain in any assessment of the performance of a repository over thousands to hundreds of thousands of years. For this reason, one part of the DOE approach to uncertainty relies on multiple lines of evidence that can contribute to the understanding of the performance of the repository. Another part of the DOE approach is a commitment to continual testing, monitoring, and analysis beyond the licensing of the site.

DOE performed a sensitivity analysis to determine the parameters that contribute most to the uncertainties in the postclosure performance results in Section 5.5. These parameters are the main contributors to variations in calculated impacts. In any case, the range of values in the distribution for these parameters exerts the strongest influence on the uncertainty of the results.

DOE used regression analysis as a tool to quantify the strength of input-output relationships in the TSPA-SEIS model. The analysis fitted an incremental linear rank regression model between individual dose at a given time (or some other performance measure) and all randomly sampled input variables. It ranked parameters on the basis of how much their exclusion would degrade the explanatory power of the regression model. The importance ranking measure that DOE used for this purpose was the partial rank correlation coefficient. This uncertainty importance factor quantifies the proportion of the total spread (variance) in total dose explained by the regression model that can be attributed to the variable of interest.

5.3.5 SENSITIVITY ANALYSIS RESULTS

For different time frames in the analysis, different epistemic parameters emerge as important to the overall uncertainty in the results (DIRS 182846-SNL 2007, all). Table 5-3 lists the results of the sensitivity analysis. The important parameters, which the table lists, are as follows:

- *IGRATE.* This parameter is the probability of an igneous event, which is the annual frequency, as a cumulative distribution function, of an intersection of the repository by a volcanic dike. As discussed in Appendix F, Section F.4.2.1.1, DOE assumed that an igneous intrusion event would destroy all drip shields and waste packages and, therefore, they would offer no barrier to seepage and radionuclide transport.

- *SCCTHRP.* This parameter is the residual stress threshold for the Alloy-22 waste package outer barrier. If the residual stress in the waste package outer barrier exceeded this threshold value, stress corrosion cracks could form, which could allow radionuclides to migrate from the waste package. The primary causes of residual stresses in the waste package outer barrier would be low-frequency, high-peak ground velocity seismic ground motions, which could cause impacts from waste package to waste package, from waste package to emplacement pallet, and from waste package to drip shield. These impacts could cause dynamic loads that dent the waste package, which could result in structural deformation with residual stress.

- *WDGCA22.* This parameter relates to the temperature dependence for the general corrosion rate of the Alloy 22 waste package outer barrier. It determines the magnitude of this temperature dependence and directly influences the short-term and long-term general corrosion rates of the Alloy 22; the larger this value the higher the earlier general corrosion rates during the thermal period and the lower the long-term corrosion rates when the repository temperatures are near ambient in-situ temperature.

Table 5-3. Top-ranking uncertainty importance parameters.

Time after closure (years)	Two most important parameters	
3,000	SCCTHRP	IGRATE
5,000	SCCTHRP	IGRATE
10,000	SCCTHRP	IGRATE
125,000	IGRATE	SCCTHRP
250,000	WDGCA22	IGRATE
500,000	IGRATE	WDGCA22
1,000,000	IGRATE	WDGCA22

Source: DIRS 182846-SNL 2007, all.

The parameters in Table 5-3 that most affect the total uncertainty in the TSPA-SEIS model are factors that would govern degradation of the waste packages or the rate at which igneous intrusion would destroy all waste packages.

5.4 Locations for Impact Estimates

Yucca Mountain is in southern Nevada in the Mojave Desert. It is in a dry, semiarid region with linear mountain ranges and intervening valleys, current average rainfall that ranges from about 100 to 250 millimeters (4 to 10 inches) a year, sparse vegetation, and a low population. This section describes the regions where possible human health impacts could occur.

Figure 5-3 shows the general direction of groundwater movement from Yucca Mountain. Shading indicates major areas of groundwater discharge through a combination of springs and evapotranspiration by plants. The general path of water that infiltrates through Yucca Mountain is south toward Amargosa Valley into and through the area around Death Valley Junction in the lower *Amargosa Desert*. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa (DIRS 100376-Czarnecki 1990, pp. 1 to 12), and spring discharge in Death Valley is a possibility (DIRS 100131-D'Agnese et al. 1997, pp. 64 and 69). Although groundwater from the Yucca Mountain vicinity flows under and to the west of Ash Meadows in the volcanic tuff or alluvial aquifers, the carbonate aquifer feeds the surface discharge areas at Ash Meadows and Devils Hole (Figure 5-3). While these two aquifers are connected at some locations, the carbonate aquifer has a hydraulic head that is higher than that of the volcanic or alluvial aquifer. Because of this pressure difference, water from the volcanic aquifer does not flow into the carbonate aquifer; rather, the reverse occurs. Therefore, contamination from Yucca Mountain is not likely to mix with carbonate aquifer waters and discharge to the surface at Ash Meadows or Devils Hole (DIRS 104983-CRWMS M&O 1999, all) under current conditions.

Because there would be no contamination of this discharge water under current conditions, no human health impacts would be expected. Further, no impacts to the endangered Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*) or Devils Hole pupfish (*Cyprinodon diabolis*) at those locations would be expected.

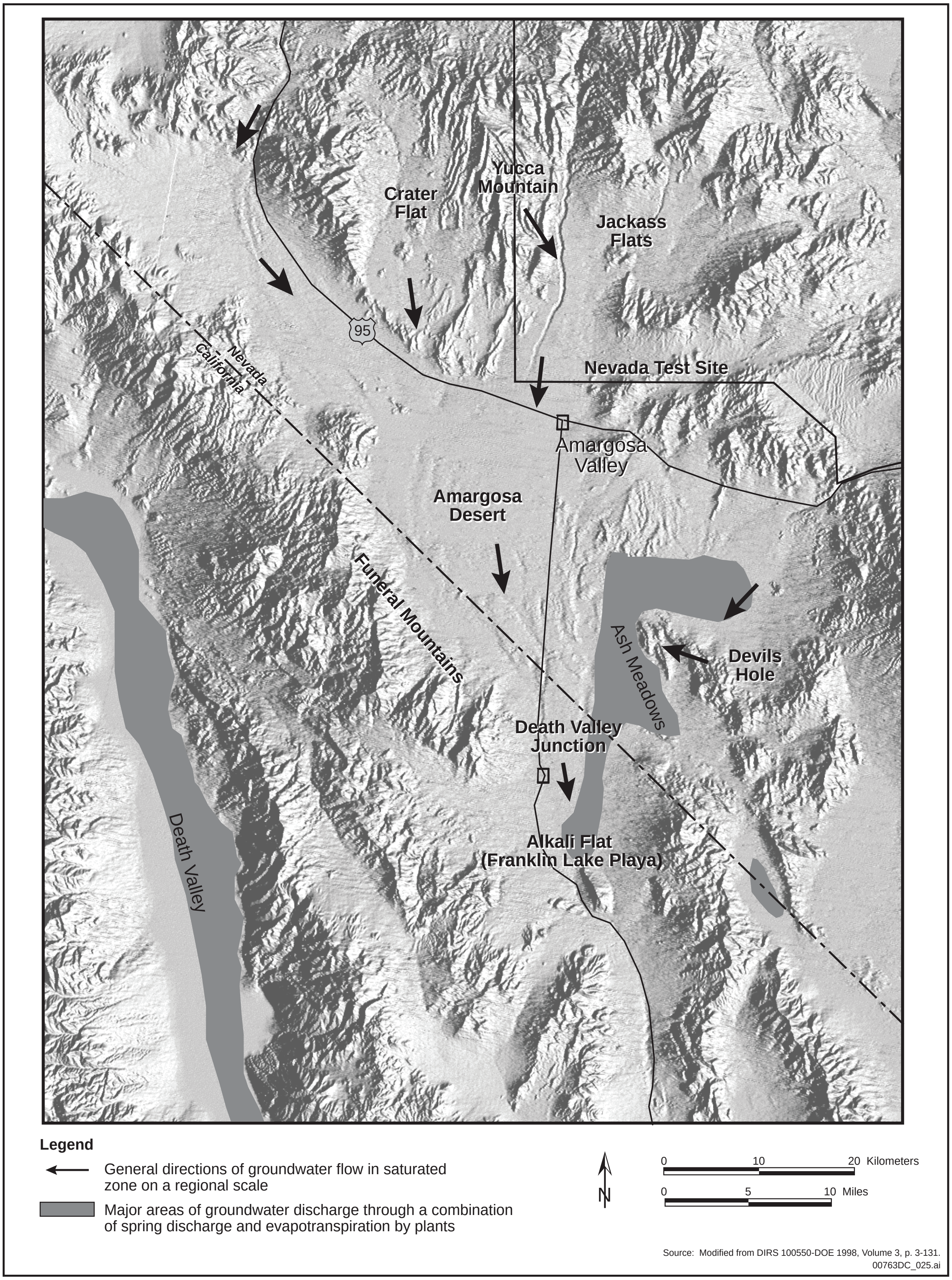

Figure 5-3. Saturated groundwater flow system.

5.5 Postclosure Radiological Impacts

The following sections discuss the annual committed effective *dose equivalent* to the RMEI, a hypothetical individual who would live south of Yucca Mountain. DOE assumed that these individuals would use contaminated groundwater and have lifestyle characteristics that EPA defined in 40 CFR 197.21. By definition, because of the highly conservative nature of the criteria to be applied to the RMEI, the RMEI would receive the high end of the range of potential dose distribution for the exposed population, which is called reasonable maximum exposure conditions. The following criteria are applied to the RMEI:

1. Lives in the accessible environment above the highest concentration of radionuclides in the plume of contamination. The surface of the controlled area is defined as the area, identified by passive institutional controls, that would encompass no more than 300 square kilometers (120 square miles) (40 CFR 197.2). It must not extend farther south than 36 degrees, 40 minutes, 13.661 seconds north latitude, in the predominant direction of groundwater flow, and no more than 5 kilometers (3 miles) from the repository footprint in any other direction.

2. Has a diet and living style representative of the people who now reside in the town of Amargosa Valley. DOE must use projections based on surveys of the people who live in the town of Amargosa Valley to determine their diets and living styles and use the mean values of these factors in the assessments for 40 CFR 197.20 and 40 CFR 197.25.

3. Drinks 2 liters (0.5 gallon) of water per day from wells at the location criterion 1 specifies.

The analysis converted the annual committed effective dose equivalent, referred to as the annual individual dose, to the probability of contracting a fatal cancer (a latent cancer fatality) due to exposure to radioactive materials in the water. DOE based the analysis on the radionuclide inventories presented in Section 5.2. The analysis included the entire carbon-14 inventory of the commercial spent nuclear fuel as a solid in the groundwater release models. This approach is conservative (tends to overstate the risk) because 2 percent of the carbon-14 is in the fuel as a gas (Section 5.6). Therefore, the groundwater models slightly overestimate (by approximately 2 percent) the potential impacts from carbon-14.

CALCULATION OF MEAN, MEDIAN, AND 95TH-PERCENTILE RESULTS

Because of the probabilistic nature of the TSPA results, it is informative to examine the mean and median results, which are measures of central tendencies or average values, and the 95th percentiles, which represent the high extreme values.

DOE performed probabilistic model simulations using the TSPA-SEIS model for the RMEI location [18 kilometers (11 miles) from Yucca Mountain]. Each of the probabilistic simulations used 300 separate sampled values for epistemic uncertain parameters and generated 300 realizations of annual individual dose as a function of time for up to 1 million years after repository closure. These annual individual dose histories were used to determine the mean, median, and 95th-percentile annual dose projections for the RMEI.

DOE estimated doses and groundwater impacts in this section for the RMEI location using the representative volume of 3.7 million cubic meters (3,000 acre-feet) of groundwater (10 CFR 63.332) to calculate the concentration of radionuclides. The TSPA-SEIS model collected all the radionuclides released to the groundwater in the representative volume.

The first step in building the TSPA-SEIS model was completion of the features, events, and processes screening analysis and forming of the scenario classes for inclusion in the performance assessment (Appendix F, Section F.2). This step produced the Nominal Scenario Class, Early Failure Scenario Class, and two disruptive event scenario classes that describe possible igneous and seismic events. Appendix F, Section F.2 describes these scenario classes and the modeling cases that represent them in TSPA-SEIS in greater detail.

The Nominal Scenario Class includes a single modeling case that considers the expected corrosion degradation processes of the drip shields and waste packages. The Early Failure Scenario Class considers the possible early failure of drip shields and waste packages due to manufacturing, material defects, or preemplacement operations that include improper heat treatment. This class includes two modeling cases, one for drip shield early failure and one for waste package early failure. DOE used modeling cases to represent different modes of degradation of the engineered barrier system features for separate analysis and then combined them to evaluate the total dose to the RMEI and groundwater impacts.

DOE used the Seismic Scenario Class to analyze possible seismic disruption of the repository and its effect on repository performance (Appendix F, Section F.2.11). This class includes (1) a modeling case that addresses features, events, and processes for the effects of ground motion damage to engineered barrier system features, and (2) a modeling case that addresses features, events, and processes for the effects of fault displacement damage to engineered barrier system features.

The Igneous Scenario Class includes features, events, and processes that describe the possibility that low-probability igneous activity could affect repository performance (Appendix F, Section F.2.10). This class includes the Igneous Intrusion Modeling Case, which addresses the features, events, and processes for the possibility that magma (molten rock), in the form of a dike (ridge of material), could intrude into the repository and disrupt expected repository performance. The Igneous Scenario Class also includes a Volcanic Eruption Modeling Case that includes features, events, and processes that describe an eruptive conduit that would rise through the repository, damage a number of waste packages, and erupt at the surface. This low-probability volcanic eruption could disperse volcanic tephra and entrained radionuclides into the atmosphere and deposit it on land surfaces where soil and near-surface geomorphic processes would redistribute it. In this Repository SEIS, the total annual dose to the RMEI includes the contribution of dose from the igneous eruption event (Appendix F, Section F.4.3).

All modeling cases are for groundwater release with the exception of the single atmospheric release case, the Volcanic Eruption Modeling Case. The TSPA-SEIS model implemented the various modeling cases separately to calculate annual doses and groundwater impacts at the RMEI location. It then combined the performance quantities from each modeling case appropriately to calculate total groundwater impacts and the total annual dose to the RMEI (Section 5.5.1 and 5.5.2 for the first 10,000 years and post-10,000

COLOR FIGURES

The figures illustrating results of the performance analysis presented in Chapter 5 and Appendix F can be found in color on the Office of Civilian Radioactive Waste Management website: http://www.ocwrm.doe.gov.

years, respectively). The analysis evaluated the impacts of a Human Intrusion Scenario that involves inadvertent drilling separately (Section 5.8).

The following two sections summarize the results of annual dose and groundwater performance analysis. Table 5-4 summarizes the estimated radiological impacts to the RMEI during the first 10,000 years after repository closure and for the post-10,000-year period up to 1 million years.

Table 5-4. Estimated radiological impacts to the RMEI—combined scenario classes.

	Mean		Median		95th-percentile	
	Annual individual dose would not exceed (millirem)	Probability of LCF per year	Annual individual dose would not exceed (millirem)	Probability of LCF per year	Annual individual dose would not exceed (millirem)	Probability of LCF per year
First 10,000 years	0.24[a]	1.4×10^{-7}	0.12	7.2×10^{-8}	0.71	4.3×10^{-7}
Post-10,000 years	2.3	1.4×10^{-6}	0.98	5.9×10^{-7}	11	6.6×10^{-6}

LCF = Latent cancer fatality.

a. This dose value would increase to 0.27 millirem if contributions from chlorine-36, selenium-79, and tin-126 were included as discussed in Section 5.2.1

5.5.1 POSTCLOSURE RADIOLOGICAL IMPACTS FOR THE FIRST 10,000 YEARS AFTER CLOSURE

This section presents the combined radiological results from all scenario classes that DOE considered in the assessment of repository performance. Appendix F, Section F.4.1 (for undisturbed repository performance) and Section F.4.2 (for disruptive events) summarize the radiological impacts from different scenario classes and modeling cases. Section F.4.3 summarizes the calculation of combined annual dose results.

The performance analysis for the combined scenario classes indicated that for the first 10,000 years after closure there would be very limited combined releases from all scenario classes with small radiological impacts for the total of all classes (Figure 5-4). The values in Table 5-4 indicate that for the first 10,000 years after repository closure, the mean annual individual dose to the RMEI could be approximately 0.2 *millirem*. This is about 1 percent of the EPA standard, which allows up to a 15-millirem annual committed effective dose equivalent during the first 10,000 years. In addition, the median and 95th-percentile values are well below the EPA standard as well. (The remainder of this chapter refers to the "annual committed effective dose equivalent" as the "annual individual dose.")

COMPARISON OF RESULTS WITH THE YUCCA MOUNTAIN FEIS

In the radiological dose calculations for this Repository SEIS, the impacts are for the combination of all scenario classes (nominal + seismic + early failure + igneous intrusion + volcanic eruption). The comparable section of the Yucca Mountain FEIS reported the results for the nominal scenario class and reported the additional scenario classes in separate subsections. Further, the nominal scenario class in the Yucca Mountain FEIS included damage to commercial spent nuclear fuel cladding due to seismic vibratory ground motion. Appendix F discusses the results for all scenario classes in this Repository SEIS.

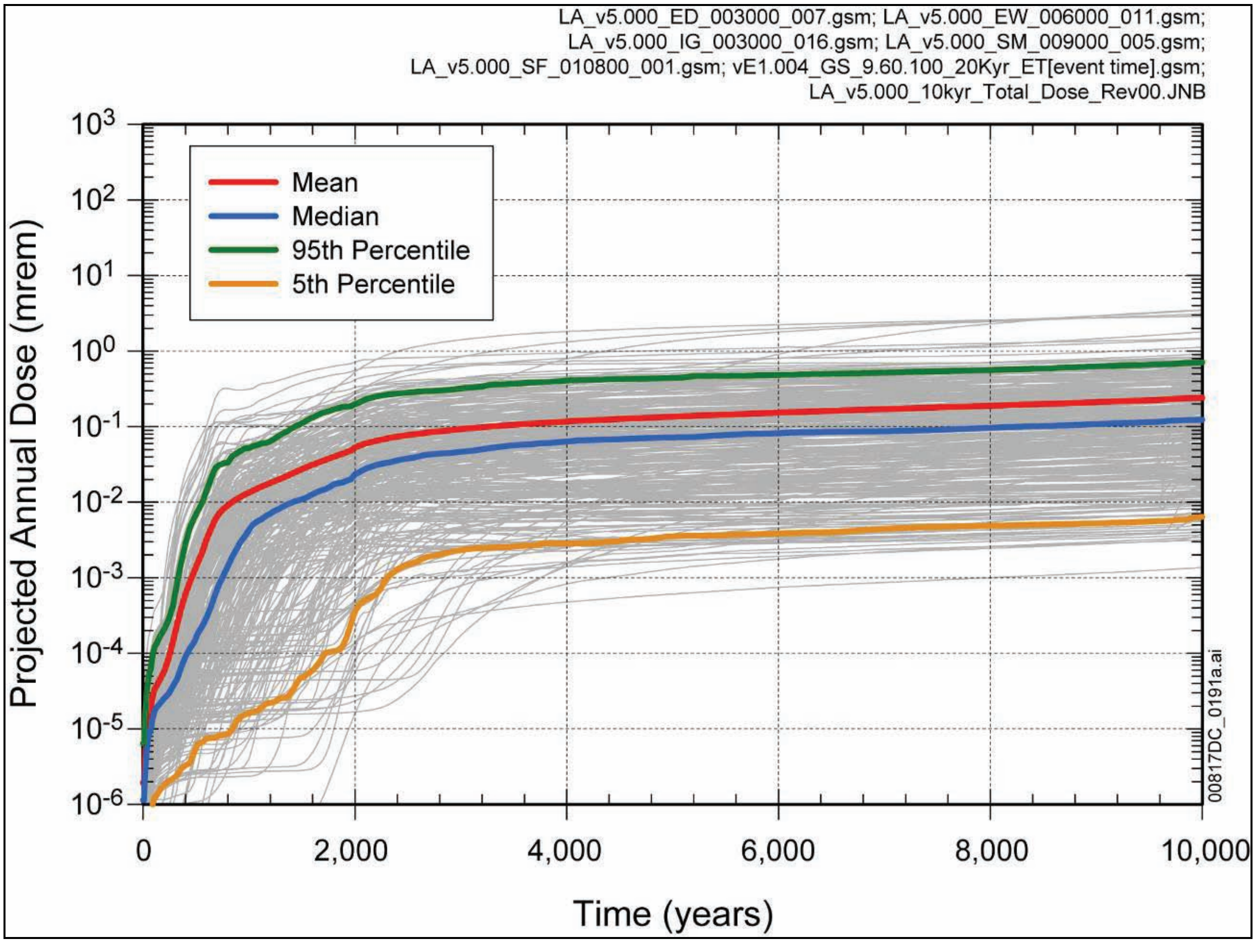

Figure 5-4. Total projected annual dose for the first 10,000 years after repository closure—combined scenario classes.

The radionuclides that would contribute the most to individual dose in the first 10,000 years would be dissolved technetium-99, carbon-14, plutonium-239, and iodine-129 in groundwater (Figure 5-5). The mean consequence at 18 kilometers (11 miles) has technetium-99 contributing more than 50 percent of the total annual individual dose rate, carbon-14 contributing approximately 15 percent, and plutonium-239 and iodine-129 each contributing approximately 10 percent. Plutonium-240 and neptunium-237 would provide additional, smaller contributions. The groundwater modeling for this waterborne radiological impacts analysis conservatively assumed that all carbon-14 migrated in the groundwater.

In relation to the groundwater protection standards in 40 CFR 197.30, both the mean and 95th-percentile estimated levels during the 10,000-year regulatory period are estimated to be substantially less than the regulatory limits (Table 5-5). As shown in the table, the 95th-percentile value for the combined radium concentration is less than the mean value. This result was a consequence of a few realizations that projected relatively high, but still small, radium concentrations that skewed the distribution of radium concentrations and caused the mean value to be higher than the 95th-percentile value. The groundwater protection standards in 40 CFR 197.30 require exclusion of unlikely natural processes and events in the performance assessment evaluation for the groundwater protection standard. Unlikely events are those that have less than one chance in 10 and at least one chance in 10,000 of occurring within 10,000 years of disposal. Likely events are those that have a 10 percent chance of occurring within

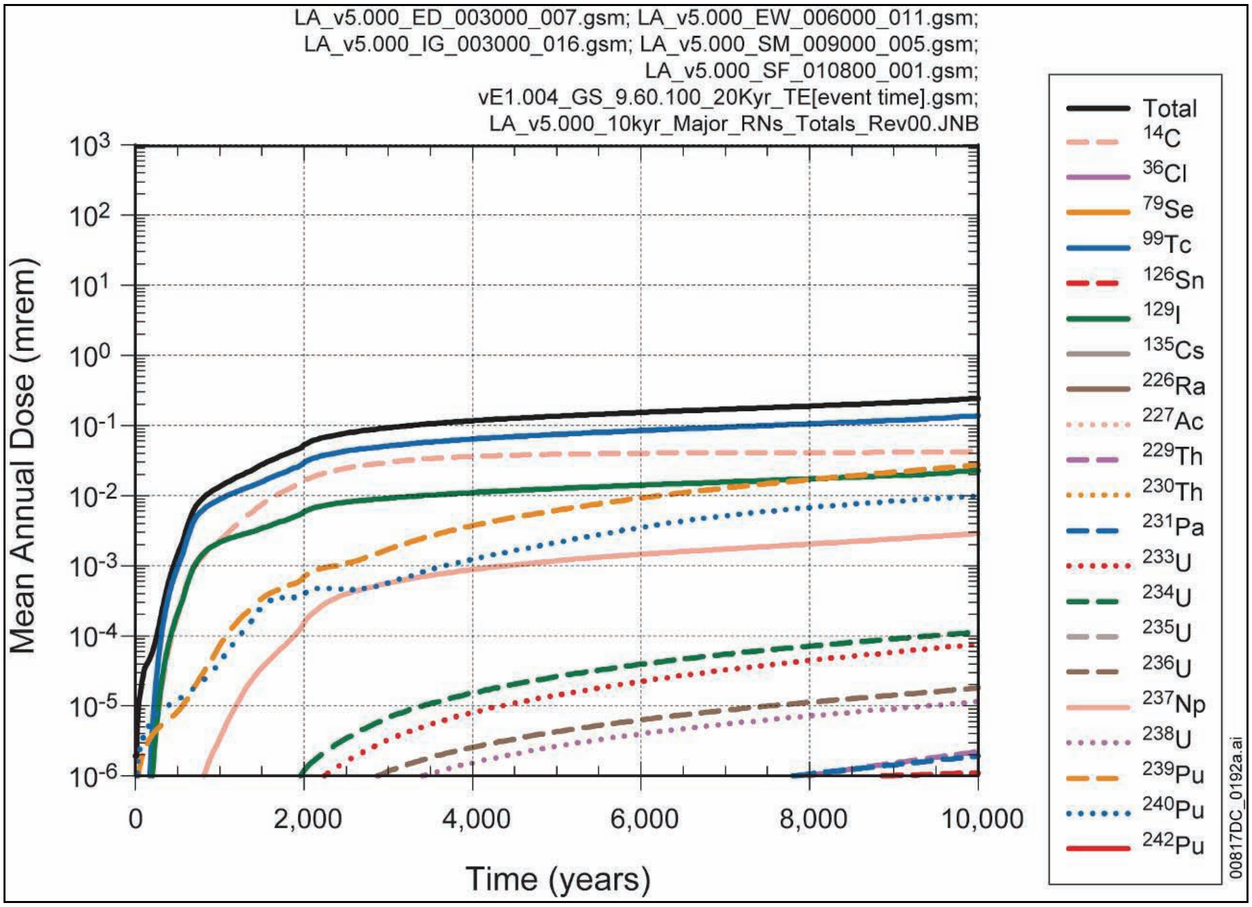

Figure 5-5. Contribution of individual radionuclides to total mean annual dose for the first 10,000 years after repository closure—combined scenario classes.

Table 5-5. Comparison of postclosure impacts at the RMEI location with groundwater protection standards during the first 10,000 years after repository closure—combined Nominal, Early Failure, and Seismic (seismic ground motion events with exceedance frequencies greater than 1×10^{-5} per year) scenario classes.

Radionuclide or type of radiation emitted	EPA limit	Mean would not exceed	95th-percentile would not exceed	Mean background
Combined radium-226 and radium-228 (picocuries per liter)	5	1.8×10^{-6}	1.3×10^{-8}	0.5
Gross alpha activity (including radium-226 but excluding radon and uranium) (picocuries per liter)	15	4.9×10^{-5}	1.2×10^{-4}	0.5
Combined beta- and photon-emitting radionuclides (millirem per year) to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	0.2	0.6	Background not included in limit

Source: DIRS 182846-SNL 2007, all.
Note: Conversion factors are on the inside back cover of this Repository SEIS.

10,000 years of disposal. Therefore, the assessment of groundwater protection included the Nominal Scenario Class, the Early Failure Scenario Class, and the likely portion of the seismic ground motion. The seismic ground motion modeling case of the seismic scenario class extends across the likely-unlikely boundary. That is, ground motions potentially occur with recurrence frequencies that are both above and below 1 chance in 10 within 10,000 years of disposal.

5.5.2 POSTCLOSURE RADIOLOGICAL IMPACTS FOR THE POST-10,000-YEAR PERIOD AFTER CLOSURE

Table 5-4 lists estimated individual doses to the RMEI for the post-10,000-year period in mean, median, and 95th-percentile values. Figure 5-6 shows the mean, median, 5th- and 95th-percentile annual individual doses at the RMEI location up to 1 million years after repository closure. The values in Table 5-4 indicate that for the post-10,000-year period, the mean and median annual individual doses could be approximately 2.3 millirem and 0.98 millirem, respectively. The estimated median value is about 0.3 percent of the proposed EPA standard, which allows up to a 350-millirem annual committed effective dose equivalent for the post-10,000-year period. In addition, the mean and 95th-percentile values are well below the EPA standard.

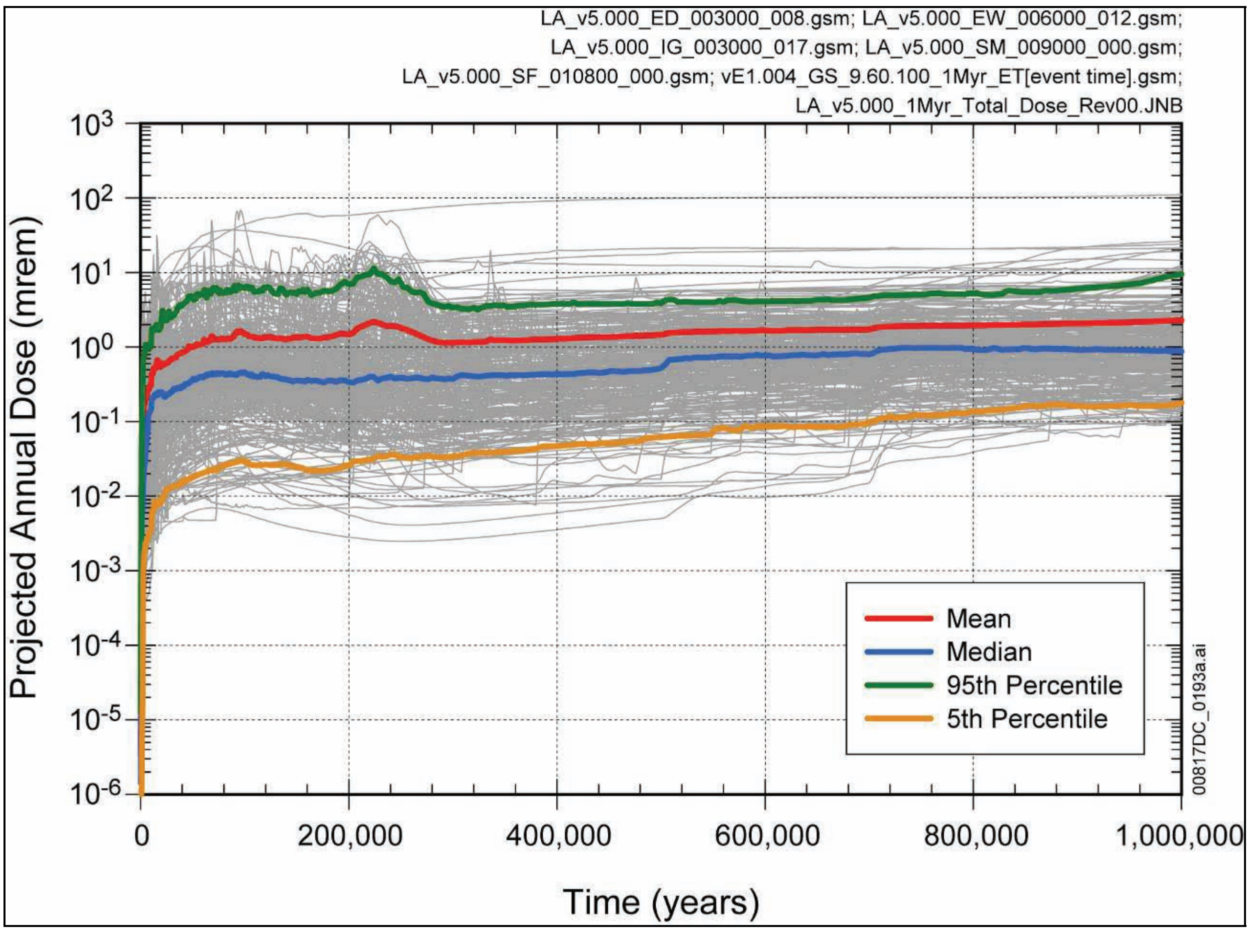

Figure 5-6. Total projected annual dose for the post-10,000-year period—combined scenario classes.

The radionuclides estimated to contribute the most to the mean annual individual dose would be radium-226, plutonium-242, neptunium-237, and iodine-129 (Figure 5-7). The mean annual individual dose at the RMEI location is estimated to have radium-226 contributing approximately 40 percent, plutonium-242 and neptunium-237 each contributing about 25 percent, and iodine-129 about 8 percent to the mean annual dose.

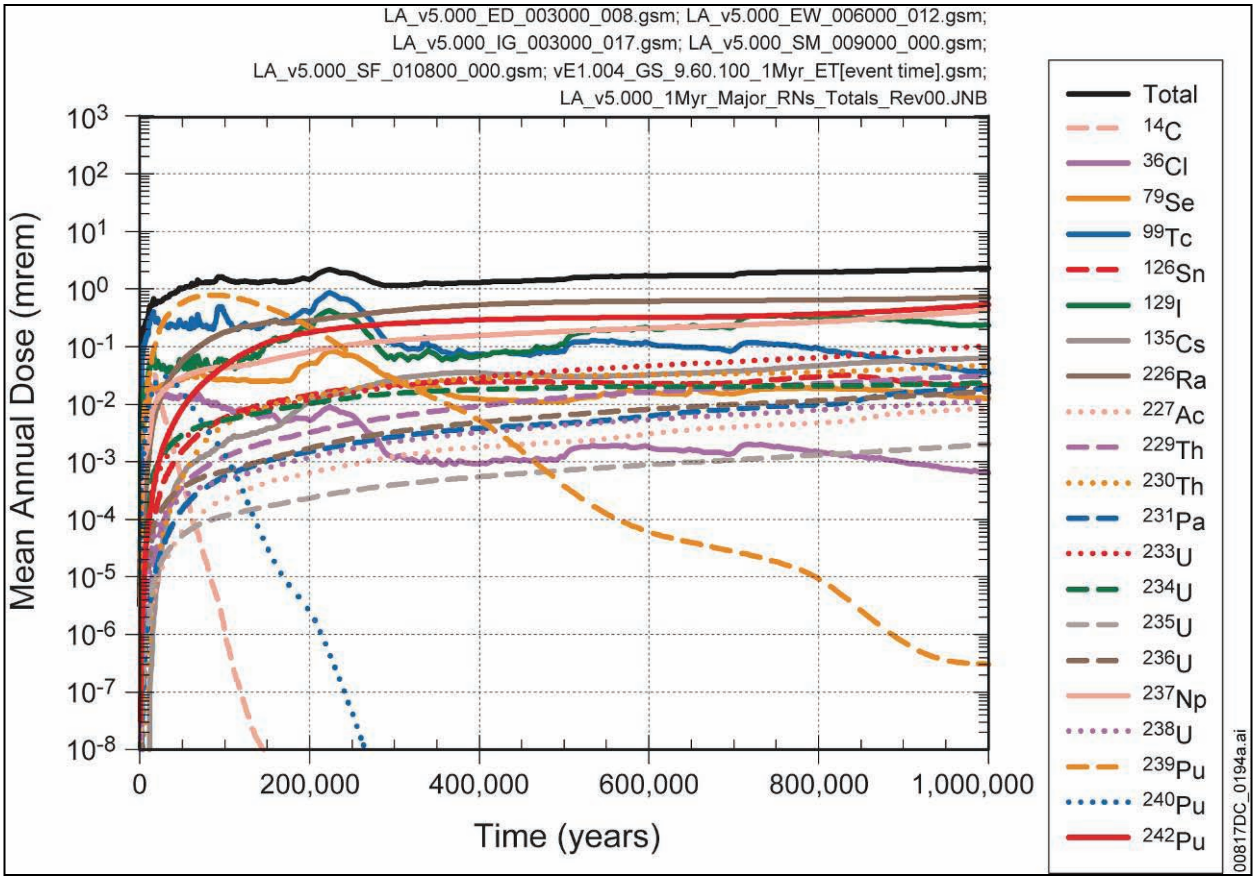

Figure 5-7. Contribution of individual radionuclides to total mean annual dose for the post-10,000-year period—combined scenario classes.

5.6 Atmospheric Radiological Impacts from Other than Volcanic Eruption

The Yucca Mountain FEIS contained an analysis of the radiological impacts of atmospheric release from other than volcanic eruption. There are no changes to the *Proposed Action* that would have a significant effect on source terms or release rates. Because the results showed extremely small effects, there would be no significant change to the information the FEIS presented if DOE performed a new analysis. This section summarizes the analysis and results from the FEIS. DOE did not update the results to the new latent cancer fatality conversion factor or the increase in population; these adjustments would have resulted in about a 50-percent increase but would not significantly change the low order of magnitude quantities. DOE has incorporated the more detailed discussion on atmospheric radiological impacts by reference to Appendix I, Section I.7 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. I-62 to I-67).

After DOE closed the repository, there would be limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. Still, the rock is porous and does allow gas to flow. Therefore, in the Yucca Mountain FEIS, DOE analyzed possible airborne releases. In the FEIS, a screening analysis showed that a full analysis was necessary only for carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and, therefore, would be more likely to dissolve in infiltrating water rather than migrate as a gas. The screening analysis in Appendix I, Section I.3.3 of the FEIS eliminated other gas-phase isotopes (DIRS 155970-DOE 2002, p. I-29), usually because they have short half-lives and are not decay products of long-lived isotopes. Because the radioactive decay constant for radon-222 is 0.18145 per day, radioactive decay would reduce the amount of radon-222 in the air by approximately 90 orders of magnitude to negligible levels in the time it took the air to travel from the repository horizon through 300 meters (1,000 feet) of overlying rock. Therefore, DOE anticipates no human effects from the atmospheric release of radon-222 in the waste package.

DOE used the GENII program (DIRS 100953-Napier et al. 1988, all) to model human health impacts in the Yucca Mountain FEIS for the population in the 80-kilometer (50-mile) region around the repository. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in a gas phase in the space (or gap) between the fuel and the *cladding* around the fuel (DIRS 103446-Oversby 1987, p. 92). This means that there is 0.122 *curie* of carbon-14 per waste package of commercial spent nuclear fuel at the time of emplacement.

The Yucca Mountain FEIS reported a maximum 80-kilometer (50-mile) annual population dose on the order of 1×10^{-8} *person-rem*. This dose corresponds to about 1×10^{-12} latent cancer fatality in the regional population during each year at the maximum carbon-14 release rate. This annual population radiological dose corresponds to a 70-year lifetime radiological population dose on the order of 1×10^{-6} person-rem, which corresponds to about 1×10^{-10} latent cancer fatality during the 70-year period of the maximum release.

The analysis showed that for airborne releases a *maximally exposed individual* would live 24 kilometers (15 miles) south of the repository. The location for maximum dose would depend on wind speed and direction, and the analysis considered it only for those locations where people currently reside (it is not a predetermined location). For a maximum release rate, the individual maximum radiological dose rate is estimated to be on the order of 1×10^{-13} rem per year, which corresponds to about a 1×10^{-17} probability of a latent cancer fatality. The 70-year lifetime dose is estimated to be on the order of 1×10^{-11} rem, which represents about a 1×10^{-15} probability of a latent cancer fatality.

5.7 Impacts from Chemically Toxic Materials

DOE performed an analysis that conservatively assumed a constant rate of release of chemically toxic materials (Appendix F, Section F.5.2.4). The analysis conveyed this release rate directly to the well at the RMEI location and calculated concentrations that ignored any attenuating effects from transport through the groundwater. Table 5-6 summarizes impacts estimated from this analysis. The table lists the bounding well concentrations and compares the resulting intake with the Oral Reference Dose. Note that this table does not contain values for chromium because it was screened out (see Section 5.1.2 and 5.2.2). All estimated impacts are below the standard values.

Table 5-6. Estimated impacts and applicable standards for waterborne chemically toxic materials release during 10,000 years after repository closure.

Material	Estimated concentration (milligram per liter)	Intake[a] (milligram per kilogram of body mass per day)	Intake standard: Oral Reference Dose (milligram per kilogram of body mass per day)
Molybdenum	0.04	0.001	0.005[b]
Nickel	0.19	0.005	0.02[c]
Vanadium	0.0001	0.000003	0.007[d]

Source: Appendix F, Section F.5.2.5.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Assuming daily intake of 2 liters (0.53 gallons) per day by a 70-kilogram (154-pound) individual.
b. DIRS 148228-EPA 1999, all.
c. DIRS 148229-EPA 1999, all.
d. DIRS 103705-EPA 1997, all
EPA = U.S. Environmental Protection Agency.

5.8 Impacts from Human Intrusion

This section presents the estimated radiological impacts of a hypothetical *Human Intrusion* Scenario of inadvertent drilling into the repository. EPA's proposed standard specifies the presentation of the performance assessment for the Human Intrusion Scenario separately; the proposed standard does not include this scenario as part of the TSPA requirements (Section 5.5) for the individual protection standard. The proposed EPA standard for human intrusion, however, parallels the individual protection standard in that the scenario not exceed the annual dose limit of 15 millirem for the first 10,000 years and 350 millirem for the post-10,000-year period.

5.8.1 HUMAN INTRUSION SCENARIO

DOE used the TSPA-SEIS model to analyze the radiological impacts of a Human Intrusion Scenario. The scenario assumed an inadvertent drilling into the repository that penetrated a drip shield and waste package and created a direct pathway to the groundwater. NRC defines the Human Intrusion Scenario, which includes the following drilling event characteristics (10 CFR 63.322, Section 322):

- There would be a single human intrusion as a result of exploratory drilling for groundwater [10 CFR 63.322(a)].
- The intruders would drill a *borehole* directly through a degraded waste package and into the uppermost aquifer that underlies the repository [10 CFR 63.322(b)].
- The drillers would use the common techniques and practices for exploratory drilling for groundwater in the Yucca Mountain region [10 CFR 63.322(c)].
- Careful sealing of the borehole would not occur; natural degradation processes would gradually modify the borehole [10 CFR 63.322(d)].
- No particulate waste material would fall into the borehole [10 CFR 63.322(e)].

- The exposure scenario includes only radionuclides that water would transport to the saturated zone (for example, water would enter the waste package, release radionuclides, and transport them by way of the borehole to the saturated zone) [10 CFR 63.322(f)].

- No releases would be due to unlikely natural processes and events [10 CFR 63.322(g)]. The regulation defines unlikely natural processes and events as those with a probability of less than 1 chance in 10 and at least 1 chance in 10,000 of occurring in a 10,000-year period (10 CFR 63.342).

- The conceptualization of the drilling event includes vertical transport through the unsaturated zone, horizontal transport along the saturated zone, and then withdrawal at the RMEI location. [10 CFR 63.312(a) through (e) define the RMEI exposure characteristics.]

The EPA standard specifies that the DOE must: (a) determine the earliest time after *disposal* that a waste package would degrade sufficiently that a drilling intrusion could occur, (b) demonstrate a reasonable expectation that the RMEI would not receive an annual dose of 15 millirem within the first 10,000-year period after closure or 350 millirem within the post-10,000-year period, and (c) perform a consequence analysis that includes all potential environmental pathways of radionuclide transport and exposure (40 CFR 197.25).

To address the first requirement of the human intrusion standard [40 CFR 197.25(a)], DOE performed a detailed technical analysis of the drilling intrusion scenario (DIRS 177432-SNL 2007, Section 6.7). The analysis indicated that an inadvertent penetration of a waste package without recognition by the driller was difficult to envision because of the design of the engineered barriers (drip shields and waste packages). The materials that were used to fabricate the drip shields and waste packages would have very high strength and resistance to a variety of degradation mechanisms. It is more plausible that the engineered barriers would deflect or divert a borehole that penetrated the repository. Moreover, based on considerations such as drill penetration rates (in rock versus the engineered barriers) and loss of drilling fluids, it is also more plausible that the drillers would recognize the intrusion.

The findings of the detailed analysis notwithstanding, DOE adopted a simple conservative calculational method to estimate the earliest time for drilling intrusion. The Department based the method on the fact that the waste package would be susceptible to drilling once the drip shield failed, which is defined as loss of structural integrity by plate thinning (degradation by corrosion processes) or rupture or puncture (seismic-induced damage). Therefore, if there was a drip shield failure, DOE conservatively assumed that there would be a simultaneous waste package failure and loss of structural integrity such that the driller would not recognize the intrusion.

The features, events, and processes screening analysis concluded that seismic ground motion events would be insufficient to significantly alter the mechanical properties of the drip shield, so that inadvertent intrusion would be noticed by a driller within the first 10,000 years after closure. Therefore, the estimate of time the earliest drip shield failure could occur was based on the time nominal general corrosion would fail the drip shield. The earliest time at which a drip shield could fail was estimated using a very high predicted titanium corrosion rate (0.999 quantile rate for the topside and underside of 75.44 nanometers per year). Using this conservative rate, the first failures of the drip shields due to general corrosion would not occur until approximately 200,000 years after repository closure under nominal conditions (using a drip shield thickness of 15 mm (DIRS 179354-SNL 2007, Table 4-2, Parameter Number 07-04A). Based on this analysis, the earliest time after repository closure that a waste package would degrade sufficiently such that a drilling intrusion could occur would be 200,000 years.

5.8.2 HUMAN INTRUSION IMPACTS

To address the second requirement of the human intrusion standard [40 CFR 197.25(b)], DOE conducted a TSPA-SEIS calculation for the drilling intrusion scenario. The Department used a probabilistic approach analogous to that used to evaluate conformance with the individual protection and groundwater protection standards, to evaluate the dose *risk* for the human intrusion standard. It performed dose calculations for all environmental pathways, as 40 CFR 197.25(c) specifies.

Figure 5-8 shows the mean, median, and 5th- and 95th-percentile values for the annual individual doses for the post-10,000-year period that could result from a human intrusion 200,000 years after repository closure for the set of 300 epistemic realizations. The values in Figure 5-8 represent the dose from a single waste package, and are not combinations of releases from other waste packages that would fail due to other processes. The mean and median annual individual doses from human intrusion are estimated to be less than 0.01 millirem and occur approximately 4,000 years after intrusion. These results indicate that the repository would be sufficiently robust and resilient to limit releases from human intrusion to values well below the individual protection standard for human intrusion of 350-millirem annual individual dose for intrusions in the post-10,000-year period.

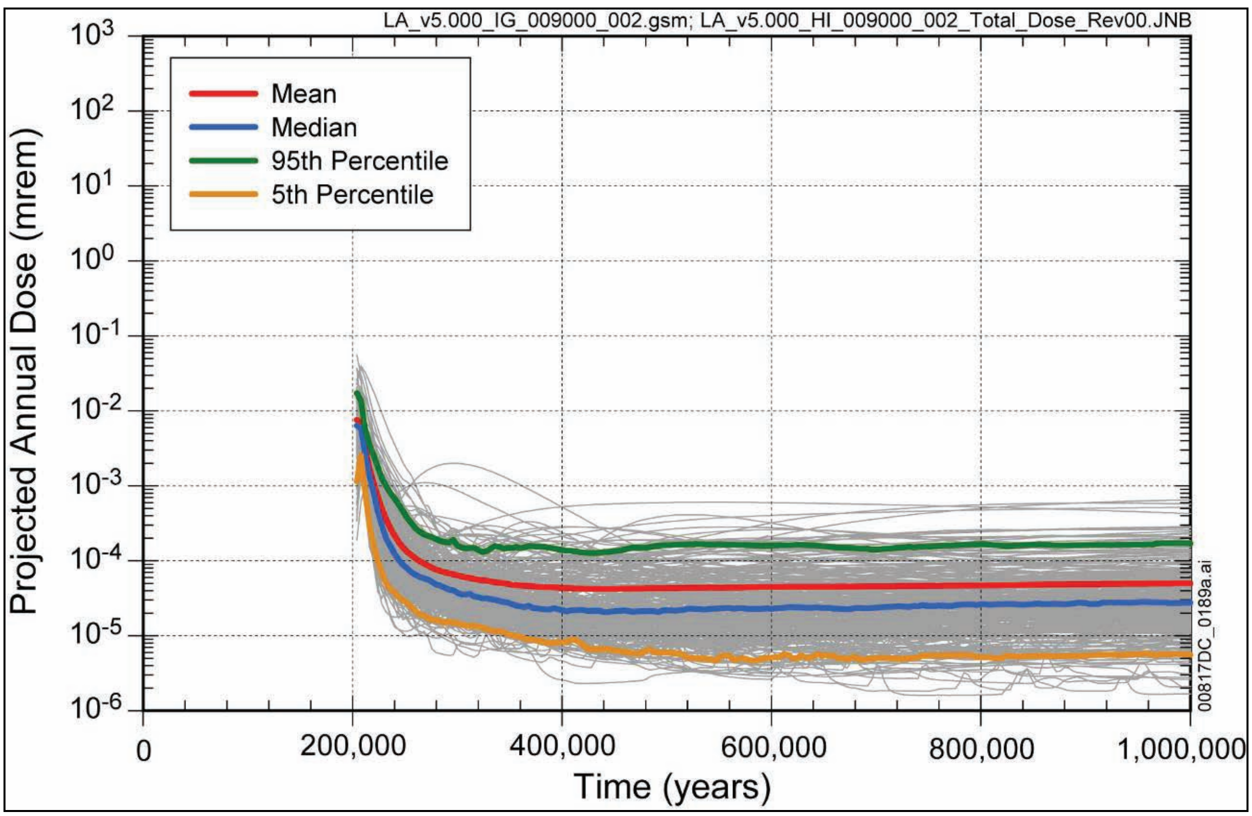

Figure 5-8. Estimated annual individual dose at the RMEI location from human intrusion 200,000 years after repository closure.

5.9 Nuclear Criticality

The Yucca Mountain FEIS contained a detailed discussion of nuclear criticality. Since the completion of the FEIS, there have been no significant changes in the waste package design or contents that would change the nuclear criticality analysis. Further, there has been no new information about the chemistry in the package or host rock environment that suggest changes to the criticality analysis should be made. Therefore, this section summarizes studies of the probability of isolated nuclear criticality events in waste packages and in surrounding rock. It incorporates by reference the more detailed discussion of criticality in Section 5.8 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 5-38 to 5-41).

One of the necessary conditions for nuclear criticality is the presence of a moderator such as water. Water could enter the waste package only if the package failed. The combination of natural and engineered barriers would greatly limit the ability of water to enter a specific package; therefore, any configuration of a waste package filled with water is very conservative.

DOE analyzed the probability of internal criticality in commercial spent nuclear fuel packages. The analysis considered factors such as package failure with water entry, loss of neutron absorbers, and degradation of internal components that would lead to a loss of internal configuration. The calculated probability of a criticality in the total inventory of the waste packages that contained commercial spent nuclear fuel is estimated be below the regulatory screening criteria for consideration (that is, less than 1 chance in 10,000 of occurring over 10,000 years) [10 CFR 63.114(d)]. In other words, criticality would not be required to be included in the TSPA model for estimating repository performance.

DOE evaluated the criticality potential of waste packages that would contain high-level radioactive waste glass and certain types of codisposed DOE spent nuclear fuel. The probability of criticality for these fuel types is estimated to be below the regulatory screening criteria for consideration (that is, less than 1 chance in 10,000 of occurring over 10,000 years) [10 CFR 63 Part 114(d)]. In comparison to a waste package for commercial spent nuclear fuel, a DOE spent fuel package would have lower fissile loading and greater flexibility in the use of a neutron absorber.

The design of the immobilized plutonium waste form would make criticality virtually impossible. The degradation rate of the ceramic waste form is so slow that, in the unlikely event that the waste package was breached and filled by a continuous dripping of water, it would be nearly 50,000 years after emplacement before enough of this waste form degraded to permit a significant separation of the uranium and plutonium from the gadolinium and hafnium neutron absorbers. Even if extremely unlikely chemistry conditions occurred that made the gadolinium sufficiently soluble to be removed before the fissile material, enough of the completely insoluble hafnium would remain to prevent criticality.

DOE also evaluated the probability of external criticality. This event, while highly unlikely, could occur if there were a release of enough fissile material from the waste package. The probability of an external criticality in the repository or the rock beneath it after repository closure is estimated to be much less than the regulatory criteria for excluding it from consideration.

DOE analyzed the potential effects of a steady-state criticality on the radionuclide inventory. If a steady-state criticality occurred, it would be unlikely to have a power level greater than 5 kilowatts. As the power level increased, the temperature would rise, which would evaporate any water. Water would be a moderator for neutrons so, as the water evaporated, the power would tend to decrease. In other words, the power would be self-limiting. For a typical commercial spent nuclear fuel waste package, a steady-state criticality would result in an increase of the inventory of certain radionuclides in that waste package. For the conservative duration of 10,000 years, this increase is estimated at less than 30 percent for the radionuclides in that package. DOE evaluated the incremental impact of steady-state criticality events on the total inventory for the repository, and anticipates that it would be insignificant.

In the extremely unlikely event that a transient criticality occurred, a rapid initiating event could produce a peak power level of up to 10 megawatts for less than 60 seconds. After this brief period, rapid boiling of the water moderator would shut down the criticality. The short duration would limit the increase in radionuclide inventory to a factor of 100,000 smaller than that of the 10,000-year steady-state criticality. Other impacts of a transient criticality would be a peak temperature of 233°C (451°F) and a peak overpressure of 20 atmospheres. Both conditions would last 10 seconds or less and would be unlikely to cause enough damage to the waste package or change its environment enough to have a significant impact on repository performance.

In the case of autocatalytic criticality, there would have to be such a high concentration of fissile material that there would be an excess of critical mass and high rates of *fission* could occur before any of the shutdown mechanisms occurred. The result could be a "runaway" *chain reaction*, which could result in a steam explosion or, in the case of a nuclear bomb, a nuclear explosion. Such a configuration is extremely difficult to achieve and requires very deliberate engineering. An autocatalytic criticality is not credible for the proposed repository. Because the igneous rock at Yucca Mountain is unlikely to contain deposits that could efficiently accumulate fissile material, the probability of creating such a critical mass would be so low as to be not credible.

In addition, DOE studied the potential impacts of disruptive natural events, such as seismic activity or igneous intrusion, on the risk of criticality in the repository and concluded that no sufficiently probable mechanisms for the accumulation of a critical mass would occur. In summary, criticality was therefore excluded from the TSPA-SEIS analysis.

5.10 Impacts to Biological Resources and Soils

DOE considered whether the proposed repository would affect biological resources in the Yucca Mountain vicinity after closure through heating of the ground surface and radiation exposure as the result of radionuclide migration through groundwater to discharge points.

Table 5-7 lists the results of soil temperature analysis for a heat loading of 85 metric tons of heavy metal (MTHM) per acre, as analyzed in the Yucca Mountain FEIS. The Proposed Action for this Repository SEIS calls for a heat loading of only 57 MTHM per acre, so the soil temperature changes would be considerably less than those analyzed in the FEIS. Therefore, DOE performed no additional analyses for biological resources and soils for the repository design and operational plan modifications made after the completion of the FEIS because DOE would expect the potential impacts to biological resources and soils to be no greater than those discussed in the FEIS. This section summarizes and incorporates by reference Section 5.9 of the FEIS, which discusses in detail the postclosure impacts to biological resources and soils (DIRS 155970-DOE 2002, pp. 5-41 to 5-43).

Surface soil temperatures would start to increase about 200 years after repository closure and would peak more than 1,000 years after closure. The temperature would then gradually decline and would

Table 5-7. Estimated temperature changes of near-surface soils under an 85-MTHM-per-acre thermal load scenario.

Soil depth (meters)	Predicted temperature increase	
	Dry soil (°C)	Wet soil (°C)
0.5	1.5	0.2
1	3	0.4
2	6	0.8

Source: DIRS 103618-CRWMS M&O 1999, p. 45.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
°C = degree Celsius.

approximate prerepository conditions after 10,000 years (DIRS 103618-CRWMS M&O 1999, Figure 4-13). The maximum increase in temperature would occur directly in soils above the repository and would affect approximately 5 square kilometers (1,250 acres). The effects of repository heat on surface soil temperatures would gradually decline with distance from the repository (DIRS 103618-CRWMS M&O 1999, p. 49). The predicted increase in temperature would extend as far as 500 meters (1,600 feet) beyond the edge of the repository. A shift in the plant species composition, if any, would be limited to the area within 500 meters of the repository footprint [that is, as much as 8 square kilometers (2,000 acres)]. A shift in the plant community probably would lead to localized changes in the animal communities that depended on it for food and shelter.

Impacts to biological resources probably would consist of an increase of heat-tolerant species over the repository and a decrease of less tolerant species. In general, areas that could be affected by repository heating could experience a loss of shrub species and an increase in annual species.

Some reptiles, including the desert tortoise (*Gopherus agassizii)*, exhibit temperature-dependent sex determination (DIRS 103463-Spotila et al. 1994, pp. 103 to 116). Predicted temperature increases of clutches at that depth based on modeling results (DIRS 103618-CRWMS M&O 1999, pp. 44 to 48) would be less than 0.5°C (0.9°F). Given the ranges of critical temperatures that were reported in *Effects of Incubation Conditions on Sex Determination, Hatching Success, and Growth of Hatchling Desert Tortoises*, *Gopherus Agassizii* (DIRS 103463-Spotila et al. 1994), an increase of this magnitude would be unlikely to cause adverse effects such as sex determination.

Estimated dose rates to plants and animals are estimated at much less than 100 millirad per day. The International Atomic Energy Agency concluded that chronic dose rates less than 100 millirad per day are unlikely to cause measurable detrimental effects in populations of the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53).

The desert tortoise is the only threatened or *endangered species* in the analyzed land withdrawal area (DIRS 104593-CRWMS M&O 1999, p. 3-14). Desert tortoises are rare or absent on or around playas (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411; DIRS 103160-Bury and Germano 1994, pp. 64 and 65); therefore, DOE anticipates no impacts to this species from contaminated water resources at Franklin Lake Playa in the future.

Impacts to surface soils would be possible. Changes in the plant community as a result of the presence of the repository could lead to an increase in the amount of rainfall runoff and, therefore, an increase in the erosion of surface soils, which would increase the sediment load in ephemeral surface water in the immediate Yucca Mountain vicinity. The exact secondary impact of this sediment load is undetermined.

5.11 Summary

Impacts from radioactive materials in the waterborne pathway under the Proposed Action would dominate potential postclosure impacts to human health from a repository at Yucca Mountain. Tables 5-4 and 5-5 list estimated impacts from groundwater releases of radionuclides after repository closure. Table 5-4 summarizes the mean, median, and 95th-percentile annual individual doses to the RMEI. The estimated mean annual individual dose of 0.24 millirem at the RMEI location in Table 5-4 is about 2 percent of the limit of the 15-millirem standard in 40 CFR Part 197 for the first 10,000 years after closure. The estimated median annual individual dose of 0.98 millirem for the post-10,000-year period is less than 1 percent of the proposed limit of 350 millirem. Table 5-5 compares concentrations with groundwater protection standards and shows that the concentrations are well below the standard values.

EPA has proposed annual dose limits of 350 millirem to an individual for human intrusion (40 CFR Part 197) if it were to occur after 10,000 years following closure. The estimated mean annual dose from a human intrusion 200,000 years after repository closure is less than 0.01 millirem, or about 0.003 percent of the EPA limit.

As Table 5-6 demonstrates, significant human impacts from chemically toxic materials would be unlikely.

Atmospheric releases of carbon-14 would yield an estimated 80-kilometer (50-mile) population impact on the order of 1×10^{-10} latent cancer fatality (Section 5.6) during the 70-year period of maximum release.

As discussed in Section 5.10, DOE does not anticipate adverse impacts to biological resources from repository heating effects or the migration of radioactive materials.

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6

Environmental Impacts of Transportation

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6. ENVIRONMENTAL IMPACTS OF TRANSPORTATION

The U.S. Department of Energy (DOE or the Department) completed the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS) in February 2002. In the Yucca Mountain FEIS, DOE evaluated two national transportation scenarios, referred to as the mostly legal-weight truck scenario and the mostly rail scenario, and three Nevada transportation alternatives—shipment by legal-weight truck, by rail, and by heavy-haul truck. After DOE completed the FEIS in 2002, it issued a Record of Decision that selected the mostly rail scenario for the transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository (69 FR 18557, April 8, 2004). Since completing the FEIS, DOE has continued to develop the repository design and associated operational plans. The Department now plans to operate the repository with the use of a primarily canistered approach that calls for the packaging of most commercial spent nuclear fuel at the commercial sites in transportation, aging, and disposal (TAD) canisters and most DOE materials in disposable canisters at the DOE sites.

DOE has prepared this Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS-0250F-S1D) (Repository SEIS) to evaluate the potential environmental impacts of the current repository design and operational plans. This chapter describes the potential environmental impacts of the transportation of spent nuclear fuel and high-level radioactive waste from 72 commercial and 4 DOE sites to the Yucca Mountain site under the mostly rail scenario.

DOE has assessed potential transportation impacts of the *Proposed Action*, which include all activities necessary to transport spent nuclear fuel and high-level radioactive waste, from loading at the commercial and DOE sites to delivery at the proposed repository. Most, but possibly not all, rail shipments to the repository would use dedicated trains (see Section 2.1) (DIRS 182833-Golan 2005, all). Two examples of when DOE would use trucks include (1) shipments from generator sites that cannot handle rail *casks* would use trucks to transport truck casks to the repository, and (2) shipments from generator sites that can handle rail casks but that lack rail access would use heavy-haul trucks or barges to carry rail casks to nearby railheads for shipment to the repository.

The decision to ship most spent nuclear fuel and high-level radioactive waste to the repository by rail would require construction of a *railroad* in Nevada. In the Rail Alignment EIS, DOE considers *alignments* for the *construction* and *operation* of a *rail line* in the Caliente and Mina *rail corridors*. Therefore, in this Repository SEIS, national rail routes from the generator sites to the repository would connect to the new DOE railroad at one of two locations in Nevada—Caliente or Hawthorne. Routes that connected in the Caliente area would continue to the repository on a rail line that DOE would construct in the Caliente Corridor. Routes that connected in the Hawthorne area would continue to the repository on a DOE-built rail line in the Mina *Corridor*.

Section 6.1 summarizes changes reflected in the impacts presented in this Repository SEIS chapter from the methods and data DOE used in the Yucca Mountain FEIS to evaluate transportation impacts. Section 6.2 summarizes the impacts from loading operations at the generator sites. Section 6.3 summarizes the impacts of national transportation of spent nuclear fuel and high-level radioactive waste from the 72 commercial and 4 DOE sites to Yucca Mountain. Section 6.4 summarizes the impacts of transportation in Nevada and discusses the impacts of the construction and operation of a rail line in the Caliente or Mina

Corridor. Section 6.4 also discusses the impacts of the transportation of materials and personnel for the construction and operation of the repository, which would include workers, construction materials, *waste packages*, and *drip shields.*

Chapter 8 discusses the *cumulative impacts* related to the transportation activities described in this chapter. The following appendixes present further information and analyses on the transportation of spent nuclear fuel and high-level radioactive waste:

- Appendix A presents sensitivity analyses related to transportation activities,
- Appendix G contains details on methods and data DOE used to evaluate transportation impacts, and
- Appendix H provides information that could help readers understand the subject of nuclear waste transportation and lists regulations related to the transportation of spent nuclear fuel and high-level radioactive waste.

6.1 Changes since Completion of the Yucca Mountain FEIS

Since it completed the Yucca Mountain FEIS, DOE has modified its repository design and operational plans. There have also been changes to some of the data DOE used to estimate *radiation doses* and radiological impacts. The following sections describe the changes that most affect the estimates of potential impacts.

6.1.1 LATENT CANCER FATALITY CONVERSION FACTORS

In the Yucca Mountain FEIS, DOE based the estimates of *latent cancer fatalities* on the received radiation *dose* and on *radiation* dose-to-health effect conversion factors from International Commission on Radiological Protection Publication 60 (DIRS 101836-ICRP 1991, all). The Commission estimated that, for the general population, a collective radiation dose of 1 *person-rem* would yield 0.0005 excess latent *cancer* fatality. For radiation workers, a collective radiation dose of 1 person-rem would yield an estimated 0.0004 excess latent cancer fatality.

Since the completion of the Yucca Mountain FEIS, the Interagency Steering Committee on Radiation Standards has updated its recommended radiation dose-to-health effect conversion factors (DIRS 174559-Lawrence 2002, p. 2). The recommended conversion factor is 0.0006 excess latent cancer fatality per person-rem for workers and the general population (DIRS 174559-Lawrence 2002, p. 2); DOE has used this factor in this Repository SEIS to estimate the number of latent cancer fatalities.

For workers, an increase in the radiation dose-to-health effect conversion factor from 0.0004 to 0.0006 excess latent cancer fatality per person-rem increases the estimates of radiological impacts by 50 percent. For the general population, an increase in the conversion factor from 0.0005 to 0.0006 excess latent cancer fatality per person-rem increases the estimates of radiological impacts by 20 percent.

6.1.2 RADIATION DOSIMETRY

Releases of radioactive material into the *environment* can affect persons who come in contact with it. Mechanisms for transportation of radioactive material include air, water, soil, and food. The ways an individual or population can come into contact with radioactive material are known as *pathways*. DOE evaluated five pathways in the Yucca Mountain FEIS:

- Inhalation of radioactive material,
- Ingestion of radioactive material,
- Inhalation of previously deposited radioactive material resuspended from the ground (*resuspension*),
- External *exposure* to radioactive material deposited on the ground (*groundshine*), and
- External exposure to radioactive material in the air (*immersion* or *cloudshine*).

Dose coefficients are the factors used to convert estimates of *radionuclide* intake (by inhalation or ingestion) or exposure (by groundshine or immersion) to a radiation dose. In the Yucca Mountain FEIS, DOE used the inhalation and ingestion dose coefficients from Federal Guidance Report No. 11 (DIRS 101069-Eckerman et al. 1988, all) and the groundshine and immersion dose coefficients from Federal Guidance Report No. 12 (DIRS 107684-Eckerman and Ryman 1993, all). These dose coefficients are based on recommendations in International Commission on Radiological Protection Publication 26 (DIRS 101075-ICRP 1977, all).

The International Commission on Radiological Protection has updated its recommended dose coefficients. In this Repository SEIS, DOE uses the updated inhalation and ingestion dose coefficients from the *ICRP Database of Dose Coefficients: Workers and Members of the Public* (DIRS 172935-ICRP 2001, all) and the updated groundshine and immersion dose coefficients from *Federal Guidance Report 13, CD Supplement, Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (DIRS 175544-EPA 2002, all) to estimate the radiation doses from transportation *accidents*. These dose coefficients are based on the recommendations in International Commission on Radiological Protection Publication 60 (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from International Commission on Radiological Protection Publication 72 (DIRS 152446-ICRP 1996, all).

6.1.3 ADDITIONAL ESCORTS

In the Yucca Mountain FEIS, DOE based the estimates of transportation impacts on one escort in rural areas and two escorts in urban and suburban areas. In this Repository SEIS, the Department based estimates of transportation impacts on additional escorts in all areas (urban, suburban, and rural). DOE considers these escorts to be workers, and the presence of additional workers increases the estimates of transportation impacts.

6.1.4 DEDICATED TRAINS

This Repository SEIS reflects DOE's policy to use dedicated trains for most shipments (DIRS 182833-Golan 2005, all). For commercial spent nuclear fuel, the Department based transportation impacts on three casks per train. For *DOE spent nuclear fuel* and high-level radioactive waste, it based transportation impacts on five casks per train. In both cases, the trains would include two *buffer cars*, two locomotives, and one *escort car*. In the Yucca Mountain FEIS, DOE based impacts on the use of general freight trains with one escort car and one cask car in each shipment; the buffer cars would be the other cars in a general freight train. In general, the use of dedicated trains would reduce the impacts to members of the public because there would be fewer delays in rail yards. The only significant source of radiation exposure for escorts would be from the last cask in the train. Therefore, impacts to escorts would generally be smaller because there would be more casks in a single train rather than one cask per train. Nonradiological impacts would be greater because estimates of impacts would account for all railcars in the train (locomotives, buffer cars, cask cars, and escort cars), not just the cask cars and the escort cars.

6.1.5 AVAILABILITY OF 2000 CENSUS POPULATION DENSITY DATA AND UPDATED RAIL AND TRUCK TRANSPORTATION NETWORKS

In the Yucca Mountain FEIS, DOE used the HIGHWAY and INTERLINE computer programs to determine representative transportation routes to the repository (DIRS 104780-Johnson et al. 1993, all; DIRS 104781-Johnson et al. 1993, all) and based transportation impacts on census data it extrapolated to 2035. The TRAGIS computer program (DIRS 181276-Johnson and Michelhaugh 2003, all) has replaced HIGHWAY and INTERLINE.

For this Repository SEIS, DOE used the TRAGIS computer program (DIRS 181276-Johnson and Michelhaugh 2003, all) to determine representative transportation routes to the repository. The Department used 2000 Census data to estimate population densities along the routes. The projected start date for repository operations is 2017. Because the analysis considered that the repository would operate for 50 years, DOE extrapolated population densities along the routes from 2000 to 2067. The Department used a two-step process to do this; it used (1) Bureau of the Census population estimates for 2000 through 2030 and (2) population estimates for 2026 through 2030 to extrapolate population densities for 2031 through 2067. In Nevada, DOE used the *Regional Economic Model, Inc. (REMI)* computer model and data from the Nevada State Demographer to extrapolate population densities.

USE OF REPRESENTATIVE ROUTES IN IMPACT ANALYSIS

At this time, before receipt of a construction authorization for the repository and years before a possible first shipment, DOE has not identified the actual routes it would use to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain. However, the highway and rail routes that DOE used for analysis in this Repository SEIS are representative of routes that it could use. The highway routes conform to U.S. Department of Transportation regulations (49 CFR 397.101). These regulations, which the Department of Transportation developed for Highway Route Controlled Quantities of Radioactive Materials, require such shipments to use preferred routes that would reduce the time in transit. A preferred route is an Interstate System highway, bypass, beltway, or an alternative route designated by a state routing agency. Alternative routes can be designated by states and tribes under U.S. Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with local jurisdictions and other states. Federal regulations do not restrict the routing of spent nuclear fuel and high-level radioactive waste shipments by rail. However, for this analysis and to be consistent with rail industry practice, DOE assumed routes for rail shipments that (1) would give priority to the use of rail lines that have the most rail traffic, that are the best maintained and have the highest quality track; (2) would give priority to originating railroads; (3) would minimize the number of interchanges between railroads; and (4) would reduce the distance traveled.

For this Repository SEIS, DOE evaluated the impacts of severe transportation accidents and sabotage *events* for an urban area. The Department based the population density in this urban area on the population densities in the 20 most populous urban areas with the use of 2000 Census data. The 2000 Census data do not include Las Vegas, Nevada, among the 20 most populous urban areas. Therefore, DOE included the Las Vegas resident and tourist populations in the urban population density. Because the analysis considered that the repository would operate for 50 years, DOE extrapolated the population density in this urban area to 2067.

6.1.6 OVERWEIGHT TRUCKS

In the Yucca Mountain FEIS, DOE estimated that the trucks that carried truck casks would have gross vehicle weights less than 36,000 kilograms (80,000 pounds) and were therefore "legal-weight" (23 CFR 658.17). DOE has determined that trucks that carried truck casks would be more likely to have gross vehicle weights in the range of 36,000 to 52,000 kilograms (80,000 to 115,000 pounds). Trucks with gross vehicle weights that exceeded 36,000 kilograms would be overweight and would be subject to the permitting requirements in each state through which they traveled. Permit requirements typically address such matters as the time of day when *overweight trucks* can travel and whether they can travel on holidays and weekends. Seasonal frost restrictions might apply in some areas. Nonetheless, the impacts from the use of overweight trucks for shipments of spent nuclear fuel would be similar to the impacts from the use of legal-weight trucks. These overweight trucks are not the same as the heavy-haul trucks that DOE would use to transport rail casks from commercial generator sites to nearby railheads. Heavy-haul trucks have gross vehicle weights greater than 58,000 kilograms (129,000 pounds) and their impacts would differ from the impacts of overweight or legal-weight trucks.

6.1.7 SHIPMENT ESTIMATES

DOE has developed updated estimates of shipments that incorporate the use of TAD canisters at each commercial *reactor* site. The Department based shipment estimates on 90 percent [by *metric tons of heavy metal* (MTHM)] of the commercial spent nuclear fuel being shipped in rail casks that contained TAD canisters. Shipment of the remaining 10 percent of the commercial spent nuclear fuel would be in rail casks that contained other types of canisters such as *dual-purpose canisters* or as *uncanistered spent nuclear fuel* in truck casks.

These new estimates project the shipment of approximately 9,500 rail casks and 2,700 truck casks of spent nuclear fuel and high-level radioactive waste to the repository (DIRS 181377-BSC 2007, all). Shipment of 9,500 rail casks would require about 2,800 trains.

6.1.8 RADIONUCLIDE INVENTORIES

Appendix A of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. A-1 to A-71) provided the basis for the radionuclide inventory that DOE used in the transportation analysis in the FEIS (DIRS 155970-DOE 2002, Chapter 6 and Appendix J). Since the completion of the FEIS, the Department has updated these inventories through additional data collection and analyses:

- The radionuclide inventory for DOE spent nuclear fuel, to incorporate the inventories from *Source Term Estimates for DOE Spent Nuclear Fuels* (DIRS 169354-DOE 2004, all), and

- The radionuclide inventory for high-level radioactive waste, to incorporate the inventories from *Recommended Values for HLW Glass for Consistent Usage on the Yucca Mountain Project* (DIRS 180471-BSC 2007, all).

DOE has updated the radionuclide inventory for commercial spent nuclear fuel to incorporate the inventories from *Characteristics for the Representative Commercial Spent Nuclear Fuel Assembly for Preclosure Normal Operations* (DIRS 180185-BSC 2007, all), in which the representative pressurized-water reactor spent nuclear *fuel assembly* had a burnup of 50,000 megawatt-days per MTHM (DIRS

180185-BSC 2007, p. 47). In this Repository SEIS, DOE increased the burnup of the representative pressurized-water reactor spent nuclear fuel assembly from 50,000 to 60,000 megawatt-days per MTHM and reduced the enrichment from 4.2 percent to 4.0 percent. This is the same burnup as the representative pressurized-water-reactor spent nuclear fuel assembly that DOE used for repository shielding and waste package design (DIRS 161120-BSC 2002, Section 5.5.2) and yields slightly higher estimates of impacts than the spent nuclear fuel used for *preclosure* normal operations or the spent nuclear fuel DOE used in the Yucca Mountain FEIS. Table 6-1 lists the characteristics of the representative pressurized- and boiling-water reactor spent nuclear fuel that DOE analyzed for the Yucca Mountain FEIS and for this Repository SEIS. Appendix G, Section G.5 contains radionuclide inventories for commercial and DOE spent nuclear fuel and high-level radioactive waste.

Table 6-1. Characteristics of representative spent nuclear fuel.

	Yucca Mountain FEIS[a]		Repository SEIS[b]	
Characteristic	PWR spent nuclear fuel	BWR spent nuclear fuel	PWR spent nuclear fuel	BWR spent nuclear fuel
Burnup (MWd/MTHM)	50,000	40,000	60,000	50,000
Enrichment (weight percent)	4.2	3.5	4.0	4.0
Decay time (years)	15	14	10	10

a. DIRS 155970-DOE 2002, pp. A-21 and A-22.
b. DIRS 180185-BSC 2007, p. 47, with burnup increased from 50,000 MWd/MTHM and enrichment reduced from 4.2 percent to 4.0 percent.

BWR = Boiling-water reactor.
FEIS = Final environmental impact statement.
MTHM = Metric ton of heavy metal.
MWd = Megawatt-day.
PWR = Pressurized-water reactor.
SEIS = Supplemental environmental impact statement.

6.1.9 TRUCK AND RAIL ACCIDENT RATE AND FATALITY RATE DATA

In the Yucca Mountain FEIS, DOE used state-specific accident and fatality rate data for 1994 to 1996 (DIRS 103455-Saricks and Tompkins 1999, all) to estimate transportation impacts. For trucks, the FEIS used accident and fatality rate data from the U.S. Department of Transportation, Federal Motor Carrier Safety Administration's Motor Carrier Management Information System. Since completion of the FEIS, the Federal Motor Carrier Safety Administration has evaluated the data in the Motor Carrier Management Information System. For 1994 through 1996, it found that accidents were underreported by about 39 percent and fatalities were underreported by about 36 percent (DIRS 181755-UMTRI 2003, Table 1, p. 4, and Table 2, p. 6). Therefore, in this Repository SEIS, DOE increased the state-specific truck accident and fatalities rates by factors of 1.64 and 1.57, respectively, to account for the underreporting.

In this Repository SEIS, DOE updated rail accident rates to reflect data from 1995 to 1999 and estimated these rates from data for Class 3 track (DIRS 180220-Bendixen and Facanha 2007). Higher classes of track have lower accident rates, and the use of Class 3 track is conservative if the track is actually rated higher (Class 4 or 5). DOE anticipates that most of the distance rail shipments would travel would be on higher classes of track.

Because DOE has adopted a policy to use dedicated trains that it expects would contain 8 to 10 cars on average for most shipments to the repository, this Repository SEIS uses a combination of rail accident rates based on both train kilometers and railcar kilometers to estimate rail accident *risks.* DOE also updated rail fatality rates to reflect data from 2000 to 2004 (DIRS 178016-DOT 2005, all). These fatality rates were in terms of fatalities per railcar kilometer.

6.1.10 SHIPPING PERIOD AND REPOSITORY OPERATIONAL PERIOD

In the Yucca Mountain FEIS, DOE based transportation impacts on shipments of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste to the repository over 24 years. Because the repository could operate for up to 50 years, in this Repository SEIS the Department based transportation impacts on the shipment of the same amount of spent nuclear fuel and high-level radioactive waste over a period of up to 50 years that would start in 2017 and end in 2067.

6.1.11 SABOTAGE RELEASE FRACTIONS

In the Yucca Mountain FEIS, DOE referred to *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments* for estimates of the fraction of spent nuclear fuel materials that a sabotage event (release fractions) could release (DIRS 104918-Luna et al. 1999, all) to estimate the impacts of possible sabotage events that involved spent nuclear fuel in truck or rail casks. In this Repository SEIS, the Department used more recent estimates of release fractions from “Release Fractions from Multi-element Spent Fuel Casks Resulting from HEDD attack” (DIRS 181279-Luna 2006, all) to estimate the impacts of such events that involved spent nuclear fuel in truck or rail casks. The more recent estimates of release fractions (DIRS 181279-Luna 2006, all) are based on the release fractions in *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments* (DIRS 104918-Luna et al. 1999, all), but incorporated data from additional tests sponsored by *Gesellschaft für Anlagen - und Reaktorsicherheit* in Germany and conducted in France in 1994 that were not available for the earlier report. The information the German investigators provided was useful because the fuel pins used in the tests were pressurized to simulate the gas pressure in commercial spent nuclear fuel pins. As a consequence, these tests provided additional information that had not yet been considered and that allowed a determination of the effects of aerosol blowdown from pin-plenum gas release after a breach of the fuel pin *cladding*. These additional test data suggest that the consequences of a sabotage event in the Yucca Mountain FEIS could be overstated by a factor of between 2.5 and 12.

6.2 Impacts from Loading Activities at Generator Sites

In the Yucca Mountain FEIS, the impacts from loading activities at the generator sites were limited to placement of spent nuclear fuel into rail or truck casks; most of the commercial spent nuclear fuel was not placed in canisters before shipment. In this Repository SEIS, most commercial spent nuclear fuel would be placed in TAD canisters before shipment in rail casks, and the impacts from loading activities would include the impacts from loading these canisters. Chapter 8 addresses the impacts of loading commercial spent nuclear fuel into dual-purpose canisters as cumulative impacts. The impacts from storing commercial or DOE spent nuclear fuel or high-level radioactive waste are also addressed as cumulative impacts in Chapter 8 of this SEIS.

For rail shipments of commercial spent nuclear fuel from the generator sites, loading operations would include placement of the spent nuclear fuel into TAD canisters, placement of the TAD or other types of canisters into a rail *transportation cask*, and placement of the transportation cask on a railcar or heavy-haul truck. For truck shipments of commercial spent nuclear fuel, the generator sites would place uncanistered spent nuclear fuel in a truck transportation cask and place the truck cask on a truck trailer.

DOE would load its spent nuclear fuel and high-level radioactive waste into disposable canisters at the four DOE sites. Therefore, loading operations at the DOE sites would consist of placement of the canisters into a rail transportation cask and placement of the transportation cask on a railcar. DOE would also load a small amount of uncanistered commercial spent nuclear fuel into truck casks at the DOE sites.

This section summarizes the potential impacts to workers and members of the public of loading of spent nuclear fuel into TAD canisters, loading the TAD and other canisters into transportation casks, and loading the transportation casks onto transportation vehicles at the 72 commercial sites. It includes the potential impacts to workers and members of the public of loading canisters that contained DOE spent nuclear fuel and high-level radioactive waste into transportation casks and loading the casks onto transport vehicles at the four DOE sites.

6.2.1 TRANSPORTATION OF CANISTERS TO GENERATOR SITES

DOE would operate the repository with the use of a primarily canistered approach in which most commercial spent nuclear fuel would be packaged at the generator sites into TAD or other types of canisters. This would require shipment of about 6,500 empty TAD canisters to the commercial generator sites. These shipments of empty canisters would be made by truck. About 1,000 additional empty TAD canisters would be shipped directly to the repository to package commercial spent nuclear fuel that could not be shipped from the generator sites using rail casks. The impacts of shipping these 1,000 empty TAD canisters to the repository were included in Section 6.4.2. Prior to the loading of a truck or rail transportation cask, equipment used in the handling and loading of the cask, known as a campaign kit, would also be shipped to the generator sites. There would be about 4,900 of these shipments, which would be by truck.

The shipments of canisters would not be radioactive material shipments, so there would be no radiation dose to the public or to workers from the shipments. The campaign kits could become contaminated during use, but would be decontaminated before shipment. Therefore, the radiation dose and radiological risks of the shipment of campaign kits would be negligible.

DOE based the estimates of the number of traffic fatalities that would result from these shipments on fatality rates for 2001 through 2005 for trucks (DIRS 182082-FMCSA 2007, Table 13) and based the estimates of the number of vehicle emission fatalities that would result from these shipments on a unit risk factor of 1.5×10^{-11} fatality per kilometer per person per square kilometer (9.3×10^{-12} fatality per mile per person per square mile) (DIRS 157144-Jason Technologies 2001, p. 98). The impacts from shipping the canisters or campaign kits were based on shipping the canisters or campaign kits a distance of 3,000 kilometers (1,900 miles).

DOE estimated that a total of 1.2 traffic fatalities and about 0.23 fatality from vehicle emissions would result from the shipment of the canisters and campaign kits.

6.2.2 RADIOLOGICAL IMPACTS TO THE PUBLIC FROM LOADING AT GENERATOR SITES

Radiation doses to members of the public near generator sites could occur due to the venting of radioactive gases during the handling of spent nuclear fuel in spent fuel pools and dry transfer casks. The estimated *population dose* to members of the public within 16 kilometers (10 miles) of the generator sites would be 2.9 person-rem over the duration of loading operations (DIRS 104794-CRWMS M&O 1994, p. 3-7). In the exposed population, the estimated *probability* of a latent cancer fatality would be 0.0017 or about 1 chance in 600. The estimated radiation dose to the *maximally exposed individual* 800 meters (0.5 mile) from the generator site would be 7.7×10^{-6} rem (DIRS 104794-CRWMS M&O 1994, p. 3-6). The estimated probability of a latent cancer fatality for this individual would be 4.6×10^{-9} or about 1 chance in 200 million.

6.2.3 RADIOLOGICAL IMPACTS TO WORKERS FROM LOADING AT GENERATOR SITES

At commercial generator sites, impacts to *involved workers* would result from loading of spent nuclear fuel into canisters, loading of canisters into rail transportation casks and, at some sites, loading of spent nuclear fuel into truck casks. For DOE spent nuclear fuel and high-level radioactive waste, impacts would result from loading of canisters that contained these materials into rail transportation casks and a small amount of uncanistered commercial spent nuclear fuel into truck casks.

For the loading of spent nuclear fuel into canisters at commercial generator sites, DOE based radiation doses on utility data compiled by the U.S. Nuclear Regulatory Commission (NRC) for the loading of 87 *dry storage* canisters at four commercial sites (DIRS 181757-NRC 2002, Attachment 3; DIRS 181758-Spitzberg 2004, Attachment 2; DIRS 181759-Spitzberg 2005, Attachment 2; DIRS 181760-Spitzberg 2005, Attachment 2).

DOE used data from *Health and Safety Impacts Analysis for the Multi-Purpose Canister System and Alternatives* (DIRS 104794-CRWMS M&O 1994, pp. A-9 and A-24) to estimate radiation doses for the loading of (1) canisters that contained commercial spent nuclear fuel into rail casks and uncanistered spent nuclear fuel assemblies into truck casks, (2) canisters that contained high-level radioactive waste or DOE spent nuclear fuel into rail casks, and (3) rail casks onto rail cars and truck casks onto truck trailers.

Table 6-2 lists estimated radiological impacts for workers who would perform loading activities. The estimated collective radiation dose for these workers would be 10,000 person-rem. In the exposed population of workers, this radiation dose would result in an estimated 6.0 latent cancer fatalities. Latent cancer fatalities from loading operations would not occur among *noninvolved workers* because these workers would not be exposed to radiation from the operations. Appendix G, Section G.2 contains more details on these estimated impacts.

Table 6-2. Estimated radiological impacts to involved workers from loading and storage operations.

Worker category/impact	Dose	LCFs
Maximally exposed individual (rem)	25[a]	0.015
Involved worker population (person-rem)		
Commercial spent nuclear fuel loading	8,300	5.0
High-level radioactive waste loading	1,300	0.77
DOE spent nuclear fuel loading	510	0.30
Total involved worker population[b]	10,000	6.0

a. Based on a radiation dose of 500 millirem per year for 50 years.
b. All involved workers at all facilities.
LCF = Latent cancer fatality.

It would be highly unlikely for a radiation worker to work for the entire period of operations (50 years) and receive the administrative dose limit of 500 *millirem* per year (DIRS 156764-DOE 1999, p. 2-3) during each year of employment. The radiation dose for this worker would 25 rem. Even under such unlikely circumstances, the estimated probability of a latent cancer fatality for this worker would be about 0.015 or about 1 chance in 70.

Evaluation of loading activities at the generator sites resulted in radiological impacts to workers that were greater than the impacts DOE presented in the Yucca Mountain FEIS. The primary reasons for the increase in the impacts were the 50-percent increase in the latent cancer fatality conversion factor and the additional handling of the commercial spent nuclear fuel required when TAD canisters were loaded at the generator sites rather than at the repository.

6.2.4 INDUSTRIAL SAFETY IMPACTS FROM LOADING AT GENERATOR SITES

Table 6-3 lists estimated impacts to involved workers from industrial (nonradiological) accidents at the 72 commercial sites and 4 DOE sites. DOE based incidence and fatality rates for involved workers on Bureau of Labor Statistics data for 2005 (DIRS 179131-BLS 2006, all; DIRS 179129-BLS 2007, all) for workers in the transportation and warehousing industries. For noninvolved workers, the Department based the rates on the professional and business services industries. From these data and estimates of the number of casks that would be shipped, the estimated probability would be less than 0.25 that a fatality would occur among the involved and noninvolved workers. Appendix G, Section G.2 contains more details on these estimated impacts.

Table 6-3. Estimated industrial safety impacts to involved and noninvolved workers during loading operations.

Worker category/impact	Impact
Involved workers	
Total recordable cases	110
Lost workday cases	73
Industrial fatalities	0.24
Vehicle emission fatalities	0.00070
Traffic accident fatalities	0.13
Noninvolved workers	
Total recordable cases	8.1
Lost workday cases	4.0
Industrial fatalities	0.012
Vehicle emission fatalities	0.00018
Traffic accident fatalities	0.031

For involved and noninvolved workers who would commute to generator sites, DOE estimated that traffic fatalities would be unlikely to occur and no health impacts would result from exposure to vehicle emissions.

6.2.5 IMPACTS OF LOADING ACCIDENTS AT GENERATOR SITES

In this Repository SEIS, DOE based the impacts of accidents at the generator sites during the loading of TAD canisters and transportation casks on information in *A Pilot Probabilistic Risk Assessment of a Dry Cask Storage System at a Nuclear Power Plant* (DIRS 181343-Milliakos 2007, all). The dry cask storage system this study analyzed consisted of a multipurpose canister that would confine the spent nuclear fuel, a transfer overpack that would shield workers from radiation during preparation of the canister for storage, and a storage overpack that would shield people from radiation and mechanically protect the canister during storage. The multipurpose canister evaluated in this study would be similar to a TAD canister.

The study covered all phases of the dry cask storage process: loading fuel from the spent fuel pools into dry storage canisters, preparing canisters for storage, transferring loaded canisters into dry storage overpacks, transferring the overpacks that contained canisters outside reactor buildings, moving the loaded overpacks from reactor buildings to storage pads, and storing the overpacks containing loaded canisters for 20 years on storage pads. The potential accidents considered in this study included dropping a spent nuclear fuel assembly, a transfer cask that contained a canister loaded with spent nuclear fuel, a canister that contained spent nuclear fuel, and a storage overpack that contained a canister loaded with spent nuclear fuel. In addition, the study considered the effects of *earthquakes*, floods, high winds, lightning strikes, aircraft crashes, and pipeline explosions. It based the radionuclide inventory of spent nuclear fuel on 10-year-cooled boiling-water-reactor spent nuclear fuel. The study considered weather conditions and the population *distribution* in the vicinity of a specific boiling-water reactor site. The analysis based other parameters on characteristics of the Surry Nuclear Power Plant in Virginia.

This study quantified the impacts of accidents in terms of the probability of a latent cancer fatality within 16 kilometers (10 miles) of the site. It estimated that these probabilities would range from 1.5×10^{-12} (1 chance in 700 billion) for an accident that involved the drop of a spent nuclear fuel assembly to 3.6×10^{-4} (1 chance in 3,000) for an accident that involved the drop of a transfer cask (DIRS 181343-Milliakos 2007, p. 7-6).

6.3 Impacts Associated with National Transportation

This section presents estimates of the national impacts of the shipment of spent nuclear fuel and high-level radioactive waste from 72 commercial and 4 DOE sites to the proposed repository. It presents the potential impacts to the public and workers that could occur from incident-free (routine) transportation, transportation accidents, and potential sabotage events along across-the-country shipping routes that the shipments could use. The section also presents an overview of the methods DOE used to estimate the impacts.

The shipment of spent nuclear fuel and high-level radioactive waste would travel an average distance of 850,000 truck kilometers and 3.7 million railcar kilometers on existing highways and railroads. For comparison, the average annual total travel of trucks and trains in the U.S. is about 350 billion truck kilometers and 60 billion railcar kilometers (DIRS 181280-DOT 2006, all; DIRS 181282-AAR 2006, all). Shipments of spent nuclear fuel and high-level radioactive waste would represent a very small fraction of total national highway and railroad annual traffic (0.0002 percent for trucks, 0.006 percent for railcars, and about 0.1 percent for trains).

With the exception of occupational and public health and safety impacts evaluated in this section, because shipments of spent nuclear fuel and high-level radioactive waste would comprise only small fractions of total national highway and rail traffic, the environmental impacts of the shipments on land use and ownership; *hydrology*; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small in comparison to the impacts of other nationwide transportation activities.

To determine if pollutants of concern from truck and rail transport would degrade *air quality* in areas not in compliance with U.S. Environmental Protection Agency standards for *criteria pollutants* (*nonattainment areas*), DOE reviewed traffic volumes in those areas. The Department found that the numbers of vehicles (truck and rail) bound for Yucca Mountain would be small in relation to normal traffic volumes. Therefore, the impact on air quality in these areas would be small.

Radiological impacts of accidents on biological resources would be unlikely. A severe accident scenario in which a release of contaminated materials occurred, such as the maximum reasonably foreseeable accident scenarios in Section 6.3.3.2, would be unlikely. The probabilities of these severe accident scenarios would be about 8 in 1 million per year and the probability of severe accident in a specific location would be much less than 8 in 1 million per year. Because of the low probability of occurrence, the risk of an accident during the transport of spent nuclear fuel and high-level radioactive waste that caused adverse impacts to any endangered or *threatened species* or impacts to other plants and animals would be small.

6.3.1 METHODS TO ESTIMATE TRANSPORTATION IMPACTS

In this Repository SEIS, DOE estimates the impacts from incident-free transportation and from transportation accidents. Incident-free transportation impacts would be those from routine transportation if no accidents occurred to affect the shipment. These impacts could be from the radiation emitted from the transportation cask, which federal regulations restrict to 10 millirem per hour at a distance of 2 meters (6.6 feet) from the truck or railcar (10 CFR 71.47), or they could be from the exhaust and fugitive dust emitted by the truck or train.

Radiological impacts from transportation accidents would be a consequence of one of three possible situations. In declining order of the potential impacts that could occur:

1. A severe accident could release radioactive material from a cask.

2. A cask could emit higher levels of radiation if the shielding degraded during a severe accident.

3. As would be the case in more than 99.99 percent of all accidents, the casks and shielding would remain intact and the casks would emit normal radiation levels and remain stationary until accident recovery operations were complete.

This chapter presents estimates of traffic fatalities that could occur to quantify nonradiological impacts of accidents.

DOE used the following computer programs to estimate incident-free transportation impacts and impacts from transportation accidents for this Repository SEIS (Appendix G, Section G.6 contains more detail):

- The Total System Model program (DIRS 181377-BSC 2007, all) to estimate the number of truck and rail casks that DOE would ship to the repository,
- The TRAGIS program (DIRS 181276-Johnson and Michelhaugh 2003, all) to identify representative highway and rail routes that shipments could use and to provide estimates of the number of people who lived along these routes,
- The RADTRAN 5 program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) to estimate (1) radiation doses to populations and transportation workers during incident-free transportation and (2) radiological accident risks to populations and transportation workers from transportation accidents, and
- The RISKIND program (DIRS 101483-Yuan et al. 1995, all) to estimate (1) radiation doses to maximally exposed individuals and to the general population during incident-free transportation and (2) radiation doses to maximally exposed individuals and the general population from severe transportation accidents and from potential sabotage events.

6.3.2 IMPACTS OF INCIDENT-FREE TRANSPORTATION

This section discusses the national impacts of incident-free transportation of spent nuclear fuel and high-level radioactive waste by truck and rail from 72 commercial and 4 DOE sites to the proposed repository. Appendix G, Section G.6 contains more information on the methods and data that DOE used to estimate incident-free transportation impacts. The analysis evaluated two categories of incident-free impacts: radiological impacts to involved workers and members of the public, and impacts from vehicle emissions. DOE evaluated two cases for transportation in Nevada. In the first, impacts are based on national rail routes that would terminate in the Caliente area; subsequent travel to the repository would use the Caliente Corridor. In the second, impacts are based on national rail routes that would terminate in the Hawthorne area; subsequent travel to the repository would use the Mina Corridor.

Figure 6-1 shows the truck and rail routes DOE used to estimate transportation impacts if it used the Caliente Corridor for rail shipments. The figure also shows the locations of the 72 commercial and 4 DOE generator sites and Yucca Mountain. Figure 6-2 shows the truck and rail routes DOE used to estimate transportation impacts if it used the Mina Corridor. In both cases, the selected rail and truck routes are representative of actual routes that DOE could use.

DOE based the identification of the representative national rail routes for the analysis in this Repository SEIS on historical railroad industry routing practices. The analysis selected routes by giving priority to the use of rail lines that have the most rail traffic (which are the best maintained and have the highest quality track), giving priority to originating railroads, minimizing the number of interchanges between railroads, and minimizing the travel distance. Highway routes would conform to the routing requirements of 49 CFR Section 397.101, “Requirements for Motor Carriers and Drivers.”

Table 6-4 lists estimates of incident-free impacts for involved workers and members of the public. DOE estimated that about 4 latent cancer fatalities could occur in the population of transportation workers

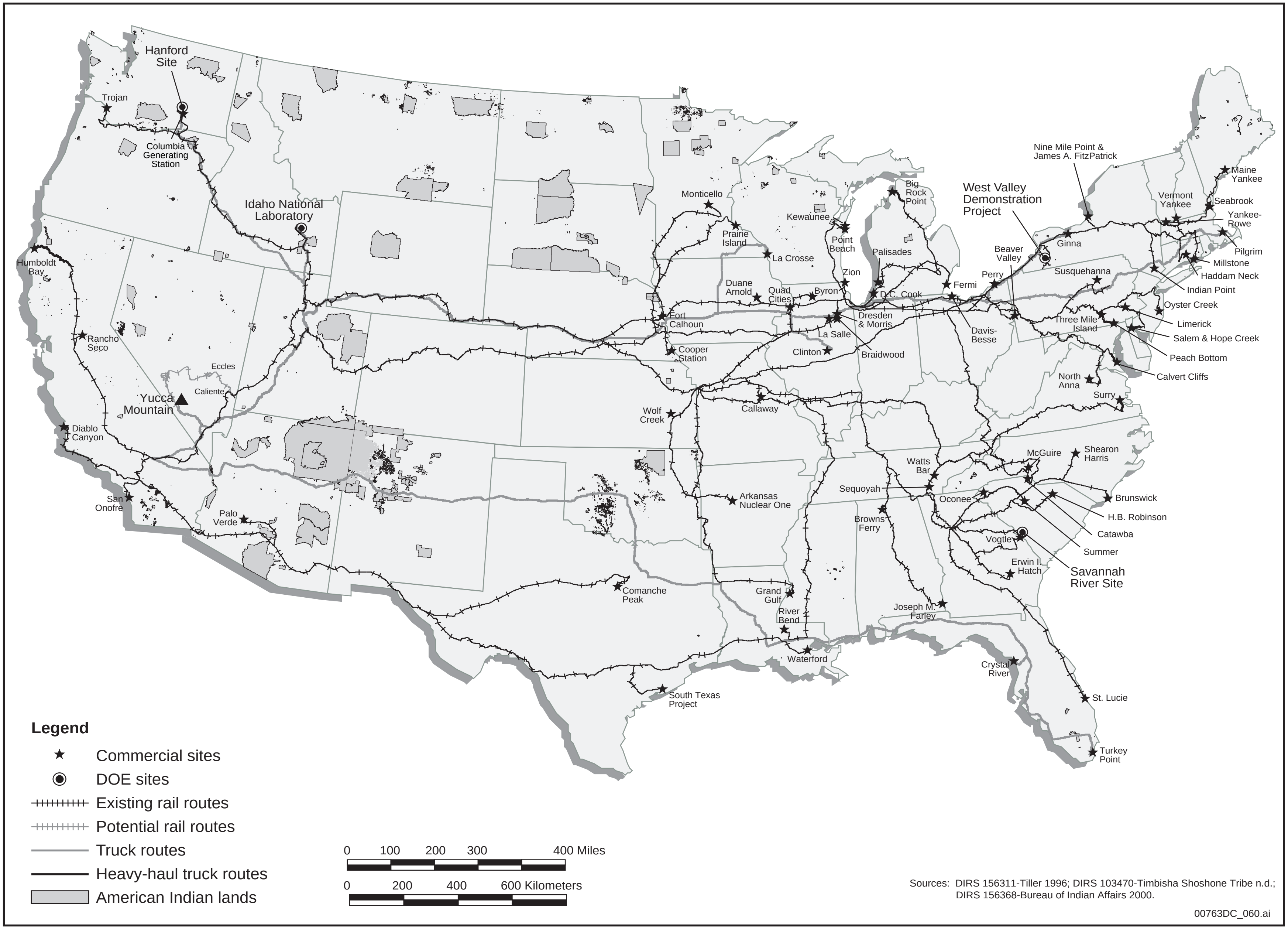

Figure 6-1. Representative rail and truck transportation routes if DOE selected the Caliente rail corridor in Nevada.

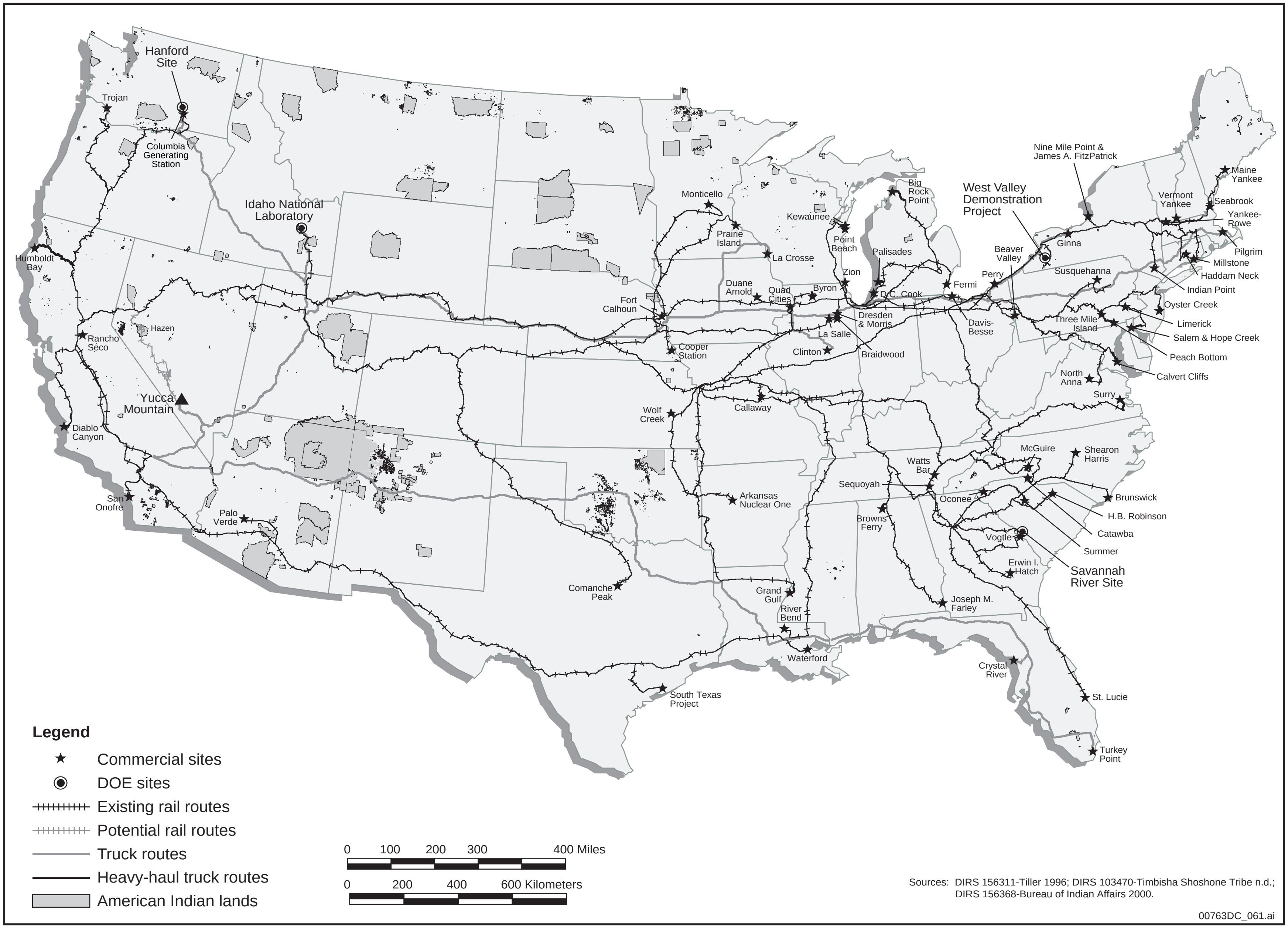

Figure 6-2. Representative rail and truck transportation routes if DOE selected the Mina rail corridor in Nevada.

Table 6-4. Estimated incident-free radiation doses and impacts for members of the public and involved workers from national transportation.[a]

Rail corridor	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (LCFs)	Involved workers (LCFs)	Vehicle emission fatalities	Total incident-free fatalities
Caliente						
Rail	800	4,700	0.48	2.8	0.99	4.3
Truck	350	880	0.21	0.53	0.13	0.87
Total	1,200	5,600	0.69	3.4	1.1	5.2
Mina						
Rail	700	5,100	0.42	3.0	0.88	4.3
Truck	350	880	0.21	0.53	0.13	0.87
Total	1,100	5,900	0.63	3.6	1.0	5.2

Note: Values are rounded to two significant figures; therefore, totals might differ from sums of values.
a. Impacts are for the entire duration (up to 50 years) of shipping spent nuclear fuel and high-level waste to the repository.
LCF = Latent cancer fatality.

exposed to radiation from the shipments. Because many workers would be involved, the risk for a individual worker would be small. DOE estimated that there would be about 1 (0.7) latent cancer fatality among members of the public who would be exposed to radiation. Because this estimate is for the entire population of exposed individuals along the transportation routes over the course of shipments to the repository, the risk for a single individual would be small. Appendix G, Section G.6 contains more details on these estimated impacts.

For nonradiological impacts of shipments, DOE estimated that vehicle emissions would result in 1 fatality among members of the public over the course of shipments along the routes to the repository. The risk for any individual would be small.

Therefore, the total estimated impacts of incident-free shipment of spent nuclear fuel and high-level radioactive waste would be about 5 fatalities. This number of fatalities, which would occur over as many as 50 years, would not be discernable from the 600,000 people who die from cancer every year in the United States.

The estimates of incident-free transportation impacts in this Repository SEIS are higher than those in the Yucca Mountain FEIS primarily due to (1) the increase in the radiation dose-to-latent cancer fatality conversion factor, (2) the use of additional shipment escorts in all areas, and (3) extrapolation of impacts to 2067. The increase in impacts due to these factors is partially offset by a decrease in impacts from the use of dedicated trains (Section 6.1.4).

Table 6-5 lists estimates of impacts for maximally exposed workers and members of the public. These impacts are at the national level and would not depend on the Nevada rail corridor that DOE selected. Among workers, escorts and inspectors would receive the highest estimated radiation doses, in large part because of their proximity to casks and the amount of time they were exposed. The maximally exposed worker would receive an estimated radiation dose of 25 rem over as many as 50 years of repository operations, based on a 500 millirem per year administrative dose limit (DIRS 174942-BSC 2005, Section 4.9.3.3). The probability of a latent cancer fatality for this worker would be 0.015 or about 1 chance in 70.

Table 6-5. Estimated incident-free radiation doses and impacts for maximally exposed involved workers and members of the public from national transportation.[a]

Category	Dose (rem)	Probability of LCFs
Involved workers		
Escort	25[b]	0.015
Rail inspector	25[b]	0.015
Railyard crew member	4.8	0.0029
Truck driver	25[b]	0.015
Truck inspector	11	0.0065
Public		
Resident along rail route	0.0078	0.0000047
Resident near rail stop	0.030	0.000018
Resident along truck route	0.00061	0.00000037
Person in traffic jam	0.016	0.0000096
Person at service station	0.21	0.00013

a. Impacts are for the entire 50-year shipping period.
b. Based on a 0.5-rem-per-year administrative dose limit.
LCF = Latent cancer fatality.

Members of the public would receive lower estimated radiation doses than workers from incident-free transportation because they would not be as close to the casks as workers and would not be exposed for as long as workers. The member of the public with the highest estimated individual radiation dose would be a service station attendant who refueled the trucks during shipments of spent nuclear fuel and high-level radioactive waste. Under assumptions that tend to overstate the risks, the same person would refuel about 600 trucks and receive an estimated radiation dose of 0.21 rem over as many as 50 years of shipments. Under these assumptions, the probability of a latent cancer fatality for this individual would be 0.00013, or about 1 chance in 8,000.

6.3.3 IMPACTS OF TRANSPORTATION ACCIDENTS

Transportation accidents that involved spent nuclear fuel or high-level radioactive waste could result in radiological impacts, nonradiological impacts, or both. Radiological impacts from a transportation accident would be a consequence of one of three possible situations identified above in Section 6.3.1.

The analysis used estimates of the number of traffic fatalities that could occur to quantify the nonradiological impacts of accidents. Together, estimates of radiological and nonradiological accident risks provide perspective on the impacts of accidents in the shipment of spent nuclear fuel and high-level radioactive waste.

To estimate the potential radiological impacts of transportation accidents, DOE performed two types of analyses. The first estimated the radiological and nonradiological risks from accidents during the transportation of spent nuclear fuel and high-level radioactive waste. The analysis of radiological risks of accidents considered a spectrum of accidents that ranged from high-probability accidents of low severity and consequences to severe accidents with radiological consequences that have a low probability of occurrence. They included accidents in which the functional performance of a cask would not be degraded, accidents in which no radioactive material would be released but shielding would be deformed because of lead shield displacement, and accidents that released radioactive material. Radiological accident risks are defined as the sum over a complete spectrum of transportation accidents of each accident's probability multiplied by its radiological consequences. For accidents in which the cask was not damaged and no radioactive materials were released, DOE based estimates of the radiation dose to the public on an estimate of the time required to recover from the accident and the radiation dose to the nearby public while recovery operations were under way.

In the second type of analysis, DOE developed estimates of the impacts of the most severe transportation accidents that could reasonably be expected to occur. These are called maximum reasonably foreseeable accidents. To be reasonably foreseeable, the transportation accident must have an expected frequency of occurrence that is greater than 1 in 10 million (0.0000001) per year (DIRS 172283-DOE 2002, p. 9). Accidents that are less frequent are not considered to be reasonably foreseeable.

Appendix G, Section G.7 describes the methods and data DOE used to estimate impacts from transportation accidents. The analysis included impacts of postulated accidents during the transportation of commercial spent nuclear fuel in truck casks by trucks from the seven commercial sites that cannot handle or load large rail casks, and from a small number of truck shipments of commercial spent nuclear fuel that would originate at the Hanford Site and the Idaho National Laboratory. The analysis considered the impacts from accidents that could involve the heavy-haul trucks that would transport spent nuclear fuel to nearby railheads from the 22 commercial sites that can load a rail cask but are not served by a railroad.

6.3.3.1 Risk of Accidents

Table 6-6 lists the radiological and nonradiological accident risks of the shipment of spent nuclear fuel and high-level radioactive waste to the proposed repository. The estimated radiological accident risk of a single latent cancer fatality for the entire population within 80 kilometers (50 miles) of the rail and truck transportation routes would be about 0.0025 (1 chance in 400) during as many as 50 years of shipments to the repository. Because this risk is for the entire population of individuals along the transportation routes, the risk for any single individual would be small.

Table 6-6. Estimated accident risks for national transportation.[a]

Rail corridor	Radiological accident dose risk (person-rem)	Radiological accident risk (LCFs)	Traffic fatalities	Total fatalities
Caliente				
Rail	4.1	0.0025	2.1	2.1
Truck	0.068	4.1×10^{-5}	0.57	0.57
Total	4.2	0.0025	2.7	2.7
Mina				
Rail	3.7	0.0022	2.2	2.2
Truck	0.068	4.1×10^{-5}	0.57	0.57
Total	3.7	0.0022	2.8	2.8

Note: Values are rounded to two significant figures; therefore, totals might differ from sums.
a. Impacts are for the entire 50-year shipping period.
LCF = Latent cancer fatality.

The estimates of radiological accident risks in this Repository SEIS are higher than those in the Yucca Mountain FEIS, primarily due to (1) the increase in the radiation dose-to-latent cancer fatality conversion factor, (2) the extrapolation of impacts to 2067, and (3) the use of the radionuclide inventory contained in

10-year-old spent nuclear fuel instead of 14- or 15-year-old spent nuclear fuel used in the Yucca Mountain FEIS.

The estimated nonradiological impacts of accidents (traffic fatalities) could be 3 fatalities during as many as 50 years of shipments to the proposed repository. For perspective, about 40,000 people die each year in traffic accidents in the United States.

6.3.3.2 Impacts of Severe Accidents

About 99.99 percent of transportation accidents would not be severe enough to result in a release of radioactive material from the transportation cask or degradation in the cask's shielding. The 0.01 percent of accidents that could result in a release of radioactive material or degradation of shielding are known as severe transportation accidents.

SEVERE TRANSPORTATION ACCIDENTS: AN OPPOSING VIEWPOINT

The State of Nevada has provided analyses that indicate that the consequences of severe transportation accidents would be much higher than those in this Repository SEIS. For example, the state has estimated that a rail accident in an urban area could result in 13 to 40,868 latent cancer fatalities in the exposed population (DIRS 181756-Lamb et al. 2001, p. 24 and 25), while DOE estimates that about 9 latent cancer fatalities would occur in the exposed population.

The state estimated these consequences using computer programs that DOE developed and uses. However, the state's analysis used values for parameters that would be at or near their maximum values. DOE guidance for the evaluation of accidents in environmental impact statements (DIRS 172283-DOE 2002, p. 6) specifically cautions against the evaluation of scenarios for which conservative (or bounding) values are selected for multiple parameters because the approach yields unrealistically high results.

DOE's approach to accident analysis estimates the consequences of severe accidents having frequencies as low as 1×10^{-7} per year (1 in 10 million) (DIRS 172283-DOE 2002, p. 9) using realistic yet cautious methods and data. DOE believes that the State of Nevada estimates are unrealistic and that they do not represent the reasonably foreseeable consequences of severe transportation accidents.

The most severe transportation accidents that would be likely to occur with a frequency of about 1×10^{-7} per year or greater are known as maximum reasonably foreseeable accidents. In general, DOE considers accidents with frequencies below 1×10^{-7} per year not to be reasonably foreseeable. Based on the 20 accident cases (Appendix G, Section G.7) the transportation accident that is reasonably foreseeable and that would have the highest (or maximum) consequences (the maximum reasonably foreseeable accident) would be expected to occur with a frequency of about 8×10^{-6} per year. This accident would involve a long-duration, high-temperature fire that would engulf a cask.

Table 6-7 lists estimates of the impacts of this severe accident. If the accident occurred in an urban area, the estimated population radiation dose would be about 16,000 person-rem. In the exposed population, this would result in an estimated 9 cancer fatalities. If the accident occurred in a rural area, the estimated population radiation dose would be about 21 person-rem, and the estimated probability of a single latent cancer fatality in the exposed population would be 0.012 (1 chance in 80). Because these risks are for the entire population exposed during the accident, the risk for any single individual would be small. In an

Table 6-7. Radiological impacts from severe transportation accidents in urban and rural areas.

Impact	Urban area	Rural area
Maximum reasonably foreseeable accident		
Population dose (person-rem)	16,000	21
LCF	9.4	0.012
Maximally exposed individual dose (rem)	34	34
Probability of LCF	0.020	0.020
First responder		
Maximally exposed responder dose (rem)	0.14 – 2.0	0.14 – 2.0
Probability of LCF	$8.2 \times 10^{-5} – 1.2 \times 10^{-3}$	$8.2 \times 10^{-5} – 1.2 \times 10^{-3}$

LCF = Latent cancer fatality.

urban area or rural area, the radiation dose from the accident for the maximally exposed individual would be 34 rem; this is based on the individual being 330 meters (1,100 feet) downwind from the accident, where the maximum dose would occur. The estimated probability of a latent cancer fatality for this individual would be 0.020 (1 chance in 50).

First responders would normally approach a transportation accident from the upwind direction to minimize their potential exposures. Therefore, DOE based the radiation dose for the first responder on exposure to radiation from a cask with degraded shielding. This individual would be between 2 and 10 meters (6.6 and 33 feet) from the damaged cask for 30 minutes. The estimated radiation dose to this first responder would range from 0.14 to 2.0 rem. The estimated probability of a latent cancer fatality for this first responder would range from 8.2×10^{-5} (1 chance in 10,000) to 1.2×10^{-3} (1 chance in 800).

6.3.4 IMPACTS OF SABOTAGE

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the United States Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements to prevent terrorists from gaining control of commercial aircraft, such as (1) more stringent screening of airline passengers and baggage by the Transportation Security Administration, (2) increased presence of Federal Air Marshals on many flights, (3) improved training of flight crews, and (4) hardening of aircraft cockpits. Additional measures have been imposed on foreign passenger carriers and domestic and foreign cargo carriers, as well as charter aircraft.

Beyond these measures to reduce the potential for terrorists to gain control of an aircraft, DOE has adopted an approach that focuses on ensuring that safety and security requirements are adequate and effective in countering and mitigating the effects of sabotage events that would involve transportation casks. The Federal Government has greatly improved the sharing of intelligence information and the coordination of response actions among federal, state, and local agencies. DOE has been an active participant in these efforts; it has regular and frequent communications with other federal, state, and local government agencies and industry representatives to discuss and evaluate the current threat environment, to assess the adequacy of security measures at DOE facilities and, when necessary, to recommend additional actions. In addition to its domestic efforts, DOE is a member of the International Working Group on Sabotage for Transport and Storage Casks, which is investigating the consequences of sabotage events and exploring opportunities to enhance the physical protection of casks.

TRANSPORTATION SABOTAGE: AN OPPOSING VIEWPOINT

The State of Nevada has provided analyses that assert that a sabotage event that used a high-energy density device such as an antitank missile would completely penetrate a spent nuclear fuel cask, which would result in consequences 10 times higher than those DOE estimated (DIRS 181892- Lamb et al. 2002, p. 19).

Within the scope of DOE's classification policy, the Department cannot state specifically the devices that the analyses in *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments* (DIRS 104918-Luna et al. 1999) and "Release Fractions from Multi-Element Spent Fuel Casks Resulting from HEDD Attack" (DIRS 181279-Luna 2006) considered. However, the analyses encompassed the damage that modern weapons could produce in a sabotage event. *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments* (DIRS 104918-Luna et al. 1999, all) does not support the assertion that modern weapons could produce full penetration of both cask walls.

In addition, in scoping comments, the State of Nevada recommended that the sabotage analysis address factors such as attacks that involve multiple weapons, attacks that use combinations of weapons to maximize release and dispersal of radioactive materials, attacks that involve large groups of well-trained adversaries, suicide attacks, attacks that involve the infiltration of trucking and railroad companies, and attacks at locations with high symbolic value.

Most of the factors listed by the state could affect the chances of success but not the outcome of the sabotage event. Because DOE already assumed that the sabotage event would occur, these factors would not alter the impacts of the sabotage event presented in this Repository SEIS. In addition, even though attacks that use multiple weapons and combinations of weapons to maximize release and dispersal of radioactive materials are possible, DOE believes that the sabotage event it analyzed encompasses the damage that modern weapons could produce in a sabotage event.

In addition, the NRC has promulgated rules (10 CFR 73.37) and interim compensatory measures (67 FR 63167, October 10, 2002) specifically to protect the public from harm that could result from sabotage of spent nuclear fuel casks. The purposes of these security measures are to minimize the possibility of sabotage and to facilitate recovery of spent nuclear fuel shipments that could come under the control of unauthorized persons. These measures include the use of armed escorts to accompany all shipments, safeguarding of the detailed shipping schedule information, monitoring of shipments through satellite tracking and a communication center with 24-hour staffing, and coordination of logistics with state and local law enforcement agencies, all of which would contribute to shipment security. The Department has committed to following these rules and measures (see 69 FR 18557, April 8, 2004).

The Department, as required by the *Nuclear Waste Policy Act*, as amended (NWPA) (42 U.S.C. 10101 et seq.), would use shipping casks certified by the NRC. Each cask design must meet stringent requirements for structural, thermal, shielding, and criticality performance and confinement integrity for routine (incident-free) and accident events. Spent nuclear fuel is protected by the robust metal structure of the shipping cask, and by cladding that surrounds the fuel pellets in each fuel rod of an assembly. Further, the fuel is in a solid form, which would tend to reduce dispersion of radioactive particulates beyond the immediate vicinity of the cask, even if a sabotage event were to result in a breach of the multiple layers of protection.

Based on this knowledge, the Department has analyzed plausible threat scenarios, required enhanced security measures to protect against these threats, and developed emergency planning requirements that would mitigate potential consequences for certain scenarios. DOE would continue to modify its approach to ensuring safe and secure shipments of spent nuclear fuel and high-level radioactive waste, as appropriate, between now and the time of shipments.

For the reasons stated above, DOE believes that under general credible threat conditions the probability of a sabotage event that resulted in a major radiological release would be low. Nevertheless, because of the uncertainty inherent in the assessment of the likelihood of a sabotage event, DOE has evaluated events in which a military jet or commercial airliner would crash into a spent nuclear fuel cask or a modern weapon (high-energy-density device) would penetrate a spent nuclear fuel cask.

In the Yucca Mountain FEIS (Appendix J, Section J.3.3.1), DOE evaluated the ability of large aircraft parts to penetrate shipping casks, and that analysis is incorporated herein by reference. In that analysis, DOE determined that the parts having the highest probability of penetrating a cask are jet engines and jet engine shafts. Accordingly, DOE undertook a penetration analysis using these parts from military aircraft (F-15/16) and from a commercial airliner (B-767), which found that the engines or shafts would not penetrate a cask and cause a release of radiological materials if an aircraft crashed into a spent nuclear fuel cask. The Department has not identified any new information that would suggest a new analysis is warranted.

To estimate the potential consequences of a sabotage event in which a high-energy-density device penetrates a rail or truck cask, DOE, in the Yucca Mountain FEIS, referred to *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments* to obtain estimates of the fraction of spent nuclear fuel materials that would be released (release fractions) (DIRS 104918-Luna et al. 1999, all). In this Repository SEIS, the Department used the more recent release fraction estimates from "Release Fractions from Multi-element Spent Fuel Casks Resulting from HEDD Attack" (DIRS 181279-Luna 2006, all) to estimate the consequences of such events involving spent nuclear fuel in truck or rail casks. These more recent estimates of release fractions (DIRS 181279-Luna 2006, all) are based on the release fractions estimated in 1999 from *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments* (DIRS 104918-Luna et al. 1999, all), but they also incorporate data from additional tests sponsored by *Gesellschaft für Anlagen - und Reaktorsicherheit* in Germany and conducted in France in 1994 that were not available for the 1999 report.

The design DOE selected for analysis was the General Atomics GA-4 Legal-Weight Truck Cask. This cask, which uses uranium for shielding, is a state-of-the-art, NRC-certified design for shipment of four pressurized-water-reactor nuclear fuel assemblies (DIRS 148184-NRC 1998, all). The design was based on the conceptual design DOE developed for a dual-purpose canister system. It is representative of large rail casks that NRC could certify for shipment of spent nuclear fuel and high-level radioactive waste.

Table 6-8 lists estimates of the impacts of potential sabotage events involving truck and rail casks. For truck casks, the analysis estimated that a sabotage event in an urban area could result in a population radiation dose of 47,000 person-rem. In the exposed population, this could cause an estimated 28 latent cancer fatalities. If the event was in a rural area, the estimated population radiation dose would be 92 person-rem. In the exposed population, the estimated risk of a single latent cancer fatality would be 0.055 (1 chance in 20). Because these risks would be for the entire exposed population, the risk for any single individual would be small. The maximally exposed individual would receive an estimated radiation dose of 43 rem, and the probability of a latent cancer fatality for this individual would be 0.026 (1 chance in 40).

Table 6-8. Estimated impacts of sabotage events involving truck or rail casks.[a]

Impact	Urban area	Rural area
Truck cask		
Impacts to populations		
Population dose (person-rem)	47,000	92
LCF	28	0.055
Impacts to maximally exposed individuals		
Maximally exposed individual dose (rem)	43	43
Probability of LCF	0.026	0.026
Rail cask		
Impacts to populations		
Population dose (person-rem)	32,000	48
LCF	19	0.029
Impacts to maximally exposed individuals		
Maximally exposed individual dose (rem)	27	27
Probability of LCF	0.016	0.016

a. Impacts are based on a sabotage event with High Energy Density Device 1 (DIRS 181279-Luna 2006, all).
LCF = Latent cancer fatality.

For rail casks, the analysis estimated that a sabotage event in an urban area could result in a population radiation dose of 32,000 person-rem. In the exposed population, this could cause an estimated 19 latent cancer fatalities. If the event was in a rural area, the estimated population radiation dose would be 48 person-rem. In the exposed population, the estimated risk of a single latent cancer fatality would be 0.029 (1 chance in 30). Because these risks would be for the entire exposed population, the risk for any single individual would be small. The maximally exposed individual would receive an estimated radiation dose of 27 rem, and the probability of a latent cancer fatality for this individual would be 0.016 (1 chance in 60).

6.3.5 ENVIRONMENTAL JUSTICE

Shipments of spent nuclear fuel and high-level radioactive waste would use the nation's existing railroads and highways. DOE estimates that transportation-related impacts to land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small. In addition, as described in the preceding sections, incident-free transportation and the risks from transportation accidents would not present a *large* health or safety risk to the population as a whole or to workers or individuals along national transportation routes. The small effect on the population as a whole would be likely for any segment of the population, which includes minorities, low-income groups, and members of American Indian tribes.

For this Repository SEIS, DOE analyzed the potential public health effects of incident-free transportation and transportation accidents. For incident-free transportation, DOE considered air emissions and doses from exposure to radioactive materials during transport. Although many people would be exposed nationwide over a long campaign, the air emissions and radiation doses to an exposed individual would be low. In this context, DOE does not consider such impacts to be high. Further, DOE has not identified any subsection of the population that would be disproportionately affected by transportation activities for the Proposed Action. Thus, the Department has concluded that no disproportionately high and adverse impacts would be likely to *minority* or *low-income populations* from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

In this Repository SEIS, DOE estimated the impacts to the general public from accidents involving transportation of spent fuel and high-level radioactive waste. The two mechanisms for such impacts are bodily trauma from collisions and exposure to radiation or radioactive material if a sufficiently severe accident occurred. The analysis estimated the impacts of a national campaign to the general public from trauma sustained in collisions with vehicles that carried spent nuclear fuel or high-level radioactive waste. DOE does not consider such impacts to be high given the number of years involved over a long shipping campaign. Further, DOE has not identified any subsection of the population that would be disproportionately affected by transportation activities for the Proposed Action. Therefore, the Department has concluded that no disproportionately high and adverse impacts would be likely to *minority* or low-income populations from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

Only a severe accident that resulted in a considerable release of radioactive material could cause serious and adverse health effects to the affected population. Because the risk of such impacts would apply to the entire population along all transportation routes, it would not disproportionately affect any minority or low-income populations.

On the basis of the analysis of incident-free transportation and transportation accidents in this Repository SEIS, the results of the transportation analysis that DOE conducted in the Yucca Mountain FEIS, and the fact that DOE has identified no subsection of the population that would be disproportionately affected by transportation for the Proposed Action, the Department has concluded that no disproportionately high and adverse impacts would be likely to minority or low-income populations from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

Section 6.4.1.8 discusses environmental justice in relation to transportation in Nevada.

6.4 Impacts Associated with Transportation in Nevada

The following sections of this chapter summarize the potential impacts of transportation within Nevada alone. Section 6.4.1 focuses on the potential impacts of DOE's "mostly rail" scenario, under which most spent nuclear fuel and high-level radioactive waste would be shipped to the repository in dedicated trains. A tabular comparison of impacts from the transportation Proposed Action and its alternatives can be found in Section 2.3, Table 2-3, of this Repository SEIS. Section 6.4.2 examines transportation impacts associated with repository operations.

6.4.1 IMPACTS OF THE MOSTLY RAIL SCENARIO IN NEVADA

In the Rail Alignment EIS, potential impacts are identified as either direct or indirect, and either short term or long term. Where practicable, DOE has quantified potential impacts. In other cases, it is not practical to quantify impacts and DOE provides a qualitative assessment of potential impacts. In the Rail

Alignment EIS, DOE has used the following descriptors to qualitatively characterize impacts where quantification of impacts was not practical:

- Small. Environmental effects would not be detectable or would be so minor that they would neither destabilize nor noticeably alter any important attribute of the resource.

- Moderate. Environmental effects would be sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

- Large. Environmental effects would be clearly noticeable and would be sufficient to destabilize important attributes of the resource.

DOE would meet all applicable regulatory requirements during construction and operation of the railroad, and would implement an array of best management practices to help ensure compliance with requirements. In addition, DOE could implement measures to mitigate impacts remaining after final design and compliance with regulatory requirements and implementation of best management practices. The following sections summarize environmental impacts for each resource area DOE analyzed.

6.4.1.1 Land Use and Ownership

The region of influence for land use and ownership is the nominal width of the rail line construction right-of-way and includes all private land, American Indian land, and public land fully or partially within that area. It also includes lands outside the nominal width of the rail line construction right-of-way, where there would be facilities, quarries, and wells to support construction and long-term operation of the railroad.

DOE would need to gain access to private land—up to 0.72 kilometer (178 acres) for the Caliente rail alignment and up to 0.59 square kilometer (146 acres) for the Mina rail alignment (Chapter 2 of this Repository SEIS, Section 2.1.7.3.1, discusses the proposed alignments and alternative segments, and the alignments are shown in Figure 2-13). For the Caliente rail alignment, another 1.15 square kilometers (284 acres) of private land would be required to accommodate support facilities. Neither rail alignment would displace existing or planned land uses over a substantial area, nor would they substantially conflict with applicable land-use plans or goals. The areas with the highest density of private land that either rail alignment would cross are the City of Caliente (Caliente rail alignment) and Goldfield (both rail alignments). For the Caliente alternative segment, some structures at the existing Union Pacific train yard and three structures along the former Pioche and Prince Branchline would need to be demolished or relocated. This Caliente alternative segment would also occupy portions of the access road and parking lot of the Caliente Hot Springs Hotel. The hotel could be adversely affected because of the loss of parking and the rail line’s proximity to guest rooms. Alternative segments near Goldfield would cross private (although vacant) land, including patented mining claims and state and county land.

In response to concerns from the Timbisha Shoshone Tribe, DOE avoided Timbisha Shoshone Trust Lands during the development of the Caliente and Mina rail alignments. The closest rail segment, common segment 5, would be approximately 3 kilometers (2 miles) east of Timbisha-Shoshone Trust Lands near Scottys Junction. DOE initially studied the Mina rail alignment with the permission of the Walker River Paiute Tribe and the Department designed the Schurz alternative segments with the aim of removing the existing Department of Defense Branchline through the town of Schurz in accordance with the Tribe's request. The Schurz alternative segments would utilize up to 0.5 percent of the land area of the Reservation (up to 5.3 square kilometers [1,300 acres]).

The Caliente rail alignment would utilize up to 162 square kilometers (40,000 acres) of Bureau of Land Management-managed land out of a total construction footprint of approximately 170 square kilometers (41,000 acres), and the Mina rail alignment would utilize up to 113 square kilometers (28,000 acres) of Bureau of Land Management-managed land out of a total construction footprint of approximately 125 square kilometers (31,000 acres).

The Mina rail alignment would cross 4.6 square kilometers (1,150 acres) of land within the Hawthorne Army Depot near its northern border, where it would not pose a conflict with the Depot's mission or land uses. Both rail alignments would cross approximately 4.1 square kilometers (1,020 acres) of DOE-managed land on the Nevada Test Site.

Railroad construction would result in surface disturbance across a number of grazing allotments on Bureau of Land Management-administered land. However, because the land would be restored after the construction phase and the operations right-of-way would be smaller than the construction right-of-way, long-term impacts would be small. Individual rail line segments would result in less than a 2-percent loss of animal unit months (a measure of the amount of forage needed to sustain one animal for 1 month) across all affected allotments for either rail alignment. The rail line could require livestock on some allotments to adjust to new routes to access water and forage. Generally, livestock could learn new routes and acclimate to and cross the rail line. The rail line could pose additional risk to ranching operations because livestock could be struck by passing trains. DOE or the railroad's commercial operator would reimburse ranchers for such losses, as appropriate.

Most of the local mining activity would be outside the rail line construction right-of-way. DOE would need to negotiate the surface rights to cross the few affected unpatented mining claims the rail line would intersect. Along the Caliente rail alignment, the rail line would intersect unpatented mining claims along South Reveille alternative segments 2 and 3; Caliente common segment 3; Goldfield alternative segments 1, 3, and 4; Oasis Valley alternative segments 1 and 3; and common segment 6. The Mina rail alignment would intersect unpatented mining claims along Montezuma alternative segments 1, 2, and 3; Oasis Valley alternative segments 1 and 3; and common segment 6. The rail line could be affected by or affect underground mining tunnels or shafts. During the final engineering design, DOE would perform a survey to verify the locations of mining tunnels and shafts and implement measures to avoid adverse impacts.

Rail alignments have been developed to avoid Wilderness Areas and other scenic and recreational areas. Under either implementing alternative, DOE would construct crossings to prevent the rail line from obstructing access to private and public land. While there could be temporary road closures or detours during the construction phase, there would be no impact to land access during the operations phase. In addition, organized off-highway vehicle events permitted in the past by the Bureau of Land Management might need to alter their routes to avoid the rail line.

The rail alignments would cross a number of utility rights-of-way. DOE would negotiate crossing agreements with right-of-way holders and the Bureau of Land Management. DOE would protect existing utilities from damage so that disruption to utility service or damage to lines would be at most small and temporary. The project would require a Bureau of Land Management right-of-way outside existing Bureau of Land Management planning corridors for utilities; this right-of-way would be outside of right-of-way avoidance areas. Under the longest potential routes, approximately 25 percent of the Caliente rail alignment and 44 percent of the Mina rail alignment (new construction on Bureau of Land Management-managed land) would fall within existing planning corridors. In addition, to avoid the proliferation of new rights-of-way, the Bureau of Land Management could elect to grant future rights-of-way for new utilities adjacent to the proposed rail line.

6.4.1.2 Air Quality and Climate

The air quality and climate region of influence for the Caliente rail alignment encompasses Lincoln, Nye, and Esmeralda Counties. The air quality and climate region of influence for the Mina rail alignment encompasses Lyon, Mineral, Esmeralda, and Nye Counties, a small portion of Churchill County near Hazen, and the Walker River Paiute Reservation, the bulk of which lies within Mineral County with smaller portions within Lyon and Churchill Counties. The Caliente and Mina rail alignments would cross desert and semi-desert areas that generally have abundant hours of cloud-free days, low annual precipitation, and large daily ranges in temperature. All portions of the Caliente and Mina rail alignments would be within areas classified by the U.S. Environmental Protection Agency as in attainment for all National Ambient Air Quality Standards.

DOE examined emissions inventories to determine county-level increases in air pollutant emissions, and performed air quality simulations to determine potential changes in air-pollutant concentrations at specific (population-center) receptors. An adverse impact to air quality would occur if it were shown that a proposed action would conflict with or obstruct implementation of a state or regional air quality management plan, or would exceed an National Ambient Air Quality Standards primary standard or contribute to existing or projected exceedances. DOE determined air pollutant concentrations that could result from railroad construction and operation along the Caliente or Mina rail alignment using the EPA-recommended model for regulatory applications (AERMOD dispersion modeling system version 07026). To assess potential air quality impacts in the region of influence from railroad construction and operation along the Caliente rail alignment DOE modeled emissions and resultant concentrations of criteria air pollutants where there are two population centers that would be near the rail line: Caliente in Lincoln County and Goldfield in Esmeralda County, and compared the modeling results to the National Ambient Air Quality Standards. DOE likewise modeled air quality for the Mina rail alignment near the population centers that would be relatively close to the rail line: Schurz, Hawthorne, and Mina in Mineral County; and in Silver Peak and Goldfield in Esmeralda County. DOE also performed modeling for the Caliente rail alignment for construction-related activities at a potential quarry site northwest of Caliente and a potential quarry site in South Reveille Valley; and for the Mina rail alignment at the potential Garfield Hills and Malpais Mesa quarry sites.

The analysis showed that criteria air pollutant concentrations along the Caliente or Mina rail alignment would not exceed the National Ambient Air Quality Standards during the construction or operations phases, with the following possible exceptions. During the construction phase for the Caliente rail alignment, the 24-hour National Ambient Air Quality Standards for PM_{10} could be exceeded during quarry operations in South Reveille Valley. During the construction phase for the Mina rail alignment, the 24-hour National Ambient Air Quality Standards for both PM_{10} and $PM_{2.5}$ (particulate matter with an aerodynamic diameter equal to or less than 2.5 micrometers) could be exceeded near the construction right-of-way at Mina and Schurz during the relatively short (less than 6 months) construction period, at the Staging Yard at Hawthorne, and at the potential Garfield Hills quarry. However, DOE would be required to obtain a Surface Area Disturbance Permit Dust Control Plan issued by the State of Nevada

Department of Environmental Protection prior to quarry and Staging Yard development. It is likely that requirements in the plan would reduce fugitive dust emissions, thus reducing the possibility of an National Ambient Air Quality Standards exceedance.

For the Caliente rail alignment, DOE determined that the highest increase in air pollutant emissions would occur during the construction phase. During the operations phase for the Caliente rail alignment, the highest increase would occur in the vicinity of the railroad operations support facilities. The highest increase in emissions would be for nitrogen oxides emissions in Nye County, where construction emissions could be as much as 8,100 metric tons (8,900 tons) per year over the county's 2002 annual nitrogen oxides emissions, which were 1,436 metric tons (1,600 tons). However, these emissions would be distributed over the entire length of the rail alignment in the county and no air quality standard would be exceeded.

For the Mina rail alignment, DOE determined that the highest increase in air pollutant emissions would occur during the construction phase. During the operations phase for the Mina rail alignment, the highest increase in air emissions from railroad operations would occur in the vicinity of the operations support facilities. The highest increase in criteria air pollutant emissions would be for nitrogen oxides in Esmeralda County during the construction phase, where emissions could be 3,570 metric tons (3,900 tons) per year higher than the 2002 county-wide nitrogen oxides emissions, which were 149 metric tons 160 tons). However, these emissions would be distributed over the entire length of the rail alignment in the county and no air quality standard would be exceeded.

Under the Shared-Use Options for both the Caliente and Mina rail alignments**,** total emissions would be increased marginally. DOE anticipates that impacts to air quality along the Caliente or Mina rail alignment under the Shared-Use Option would be similar to those under the Proposed Action without shared use. Pollutant emissions and estimated concentrations resulting from construction and operations of the railroad within the repository region of influence are detailed in Tables 6-9 through 6-14.

Table 6-9. Rail line construction pollutant release rates in the analyzed land withdrawal area from surface equipment during the construction period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	590,000	19
Sulfur dioxide	Annual	420	0.013
	24-hour	1.7	0.038
	3-hour	0.62	0.038
Carbon monoxide	8-hour	1,800	42
	1-hour	230	42
PM_{10}	24-hour	140	3.2
$PM_{2.5}$	Annual	34,000	1.1
	24-hour	140	3.1

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Based on a 12-hour release for averaging periods of 24 hours or less.

Table 6-10. Rail line construction air quality impacts from construction equipment in the analyzed land withdrawal area during the construction period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration	Regulatory limit	Percent of regulatory limit
Nitrogen dioxide	Annual	2.7	100	2.7
Sulfur dioxide	Annual	0.0019	80	0.0024
	24-hour	0.15	365	0.040
	3-hour	0.61	1,300	0.047
Carbon monoxide	8-hour	250	10,000	2.5
	1-hour	2000	40,000	5.1
PM_{10}	24-hour	12	150	8.2
$PM_{2.5}$	Annual	0.16	15	1.0
	24-hour	12	35	34

Notes: Numbers are rounded to two significant figures. Receptors at boundary of analyzed land withdrawal area.

Table 6-11. Rail Equipment Maintenance Yard and associated facilities pollutant release rates from surface equipment during the construction period in the analyzed land withdrawal area.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	84,000	2.7
Sulfur dioxide	Annual	71	0.0022
	24-hour	0.28	0.0098
	3-hour	0.11	0.0098
Carbon monoxide	8-hour	300	11
	1-hour	38	11
PM_{10}	24-hour	23	0.81
$PM_{2.5}$	Annual	5,700	0.18
	24-hour	23	0.79

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Based on an 8-hour release for averaging periods of 24 hours or less.

Table 6-12. Rail Equipment Maintenance Yard and associated facilities air quality impacts from construction equipment during the construction period in the analyzed land withdrawal area (micrograms per cubic meter).

Pollutant	Period	Maximum concentration	Regulatory limit	Percent of regulatory limit
Nitrogen dioxide	Annual	0.071	100	0.071
Sulfur dioxide	Annual	0.000058	80	0.000073
	24-hour	0.0084	365	0.0023
	3-hour	0.067	1,300	0.0052
Carbon monoxide	8-hour	27	10,000	0.27
	1-hour	220	40,000	0.54
PM_{10}	24-hour	0.7	150	0.47
$PM_{2.5}$	Annual	0.0048	15	0.032
	24-hour	0.68	35	1.9

Notes: Numbers are rounded to two significant figures. Receptors at boundary of analyzed land withdrawal area.

Table 6-13. Annual pollutant emissions (kilograms) from the Rail Equipment Maintenance Yard and associated facilities and activities during the operations period in the analyzed land withdrawal area.

	Rail Equipment Maintenance Yard	Rail Equipment Maintenance Yard trucks	Rail Equipment Maintenance Yard switch train locomotives	Fuel oil storage	Total rail facility emissions
Nitrogen dioxide	34,000	170	360,000	0	400,000
Sulfur dioxide	800	1	300	0	1,100
Carbon monoxide	10,000	190	150,000	0	160,000
PM_{10}	1,100	9.6	11,000	0	12,000
$PM_{2.5}$	1,000	8.9	9,600	0	11,000
Hydrocarbons	4,100	89	37,000	150	42,000

Source: Rail Alignment EIS.
Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums of values.

Table 6-14. Air quality impacts from the Rail Equipment Maintenance Yard and associated facilities and activities during the operations period in the analyzed land withdrawal area (micrograms per cubic meter).

Pollutant	Period	Maximum concentration	Regulatory limit	Percent of regulatory limit
Nitrogen dioxide	Annual	0.33	100	0.33
Sulfur dioxide	Annual	0.00093	80	0.0012
	24-hour	0.13	365	0.036
	3-hour	1.1	1,300	0.081
Carbon monoxide	8-hour	57	10,000	0.57
	1-hour	460	40,000	1.1
PM_{10}	24-hour	1.4	150	0.94
$PM_{2.5}$	Annual	0.009	15	0.06
	24-hour	1.3	35	3.6

Note: Numbers are rounded to two significant figures.

6.4.1.3 Physical Setting

DOE examined the region of influence for physical setting to determine the potential for impacts on physiography, geology, and soils. The region of influence for physical setting includes the areas that would be directly and indirectly affected by construction and operation of the proposed railroad, and incorporates the nominal width of the rail line construction right-of-way (300 meters [1,000 feet] centered on the rail alignment). It also includes the footprints of construction camps, quarry sites, facility sites, access roads, and water wells that would be outside the nominal width of the construction right-of-way.

DOE determined that land disturbance would be 55 to 61 square kilometers (14,000 to 15,000 acres) for the Caliente rail alignment and 40 to 48 square kilometers (9,900 to 12,000 acres) for the Mina rail alignment. Lands that are currently relatively undisturbed would be extensively graded, which would result in topsoil loss and increased potential for erosion. However, DOE would implement best management practices to minimize erosion and sedimentation during construction activities. DOE assessed that impacts from soil erosion would be small.

Perlite, a locally important mineral, occurs in the area of the Caliente rail alignment Caliente and Eccles alternative segments, and other minerals, such as limestone, metallic commercial minerals, and geothermal resources have been identified in some nearby mountains. Although no mineral resources would be removed, placement of the rail line could reduce the availability of perlite or limestone for mining. The Goldfield alternative segments would cross mining areas and could limit the boundaries for mining if mineral resources extend under the rail line.

Neither railroad construction nor operation would reduce the availability for mining of metallic minerals that have been identified in surrounding mountains. The Montezuma alternative segments would cross mining areas in the Goldfield Hills area, and could limit the boundaries for mining if mineral resources extended under the rail line.

Along the Caliente rail alignment, construction in the Caliente or Eccles alternative segment and Caliente common segment 1 would result in a small loss of up to 1.4 square kilometers (340 acres) of prime farmland soil. These prime farmland soils are found in isolated pockets and are unfarmed. In the Mina rail alignment, construction of Schurz alternative segment 1, 4, 5, or 6 would also impact soils characterized as prime farmland directly adjacent to the banks of the Walker River. These areas are not farmed and DOE expects no change in their current agricultural land use. DOE expects that impacts to prime farmland soils would be small [up to 0.014 square kilometer (3.5 acres) would be lost]. There would be a potential for leaks and spills that could contaminate soils during railroad operations; however, DOE would implement best management practices and consider mitigation measures to reduce any impacts.

The Shared-Use Option would require the construction of additional rail sidings within the rail line construction right-of-way in areas of relatively flat terrain. DOE determined that implementation of the Shared-Use Option would increase the surface disturbance area by less than 0.1 percent for either the Caliente or Mina rail alignment, and would add no impacts to physical setting beyond the permanent alterations already described.

6.4.1.4 Paleontological Resources

Paleontology is a science that uses fossil remains to study life in past geological periods. Paleontological resources are recognized as a fragile and nonrenewable record of the history of life on Earth and a critical component of America’s natural heritage and, once damaged, destroyed, or improperly collected, their scientific and educational value may be greatly reduced or lost forever. The region of influence for paleontological resources along both rail alignments is the rail line construction right-of-way, and the footprints of railroad construction and operations support facilities.

DOE used the Bureau of Land Management system to classify paleontological resource areas according to their potential for containing vertebrate fossils, or noteworthy occurrences of invertebrate or plant fossils. This classification system became the basis to analyze the magnitude of potential impacts from construction in the region of influence of the Caliente and Mina rail alignments.

DOE determined that there are no known paleontological resources along any of the Caliente or Mina rail alignments or at the proposed locations of railroad construction and operations support facilities. Therefore, the Department does not anticipate any impacts to paleontological resources during the construction or operations phase along either alignment. However, if DOE uncovered previously unknown paleontological resources during construction activities, the Department would consult with the Bureau of Land Management to develop appropriate conservation measures.

Under the Shared-Use Option for either rail alignment impacts to paleontological resources would be similar to those for the Proposed Action without shared use.

6.4.1.5 Surface-Water Resources

The region of influence for surface-water resources would be limited in most cases to the nominal width of construction right-of-way within the Caliente rail alignment or the Mina rail alignment. Railroad construction and operations along either rail alignment would potentially result in both direct and indirect impacts to surface-water resources. Many of these impacts are common impacts that would occur along the entire length of the alignment. Direct impacts would include temporary or permanent grading, dredging, rerouting, or filling of surface-water resources. Indirect impacts would include potential increases in surface flow and non-point source pollution resulting from runoff from areas where surface grades and characteristics would be changed.

DOE anticipates that during the construction phase along the Caliente rail alignment, the Staging Yard and the Interchange Yard along either the Caliente or the Eccles alternative segment would require channelization of natural drainage surface waters to keep water out of rail line operations support facility sites. Changes in drainage patterns could result in changes in erosion and sedimentation rates or locations. However, in all instances where the alignment would come close to or cross a surface-water feature, impacts would be substantially minimized by the implementation of engineering design standards and best management practices.

The Caliente alternative segment is adjacent to wetlands and some wetland fill would be unavoidable. DOE proposes to construct the Caliente alternative segment over the abandoned Union Pacific Railroad roadbed, in part to minimize filling wetlands. Of the 0.28 square kilometer (68 acres) of wetlands delineated along the rail alignment, 0.05 square kilometer (12 acres) would be filled to construct the rail line. DOE could modify the final design of the rail line to avoid additional wetlands, such as those adjacent to the old rail roadbed along Meadow Valley Wash, by using a slightly narrower construction footprint; however, this would only slightly reduce the area of wetlands that would be filled.

Approximately 0.09 square kilometer (22 acres) of wetlands could be filled to construct a quarry siding at potential quarry CA-8B along the Caliente alternative segment. Approximately 0.19 square kilometer (47 acres) of wetlands would be filled for construction of the Staging Yard at Indian Cove near Caliente. The original wetland meadow area would be drained and built up above the level of the floodplain. Constructing an active drainage system and a channel around the site to keep the area dry and in a stable condition might be necessary. The proposed channel around the site would be approximately 1,680 meters (5,500 feet) long. These actions would require permits from the U.S. Army Corps of Engineers, and compliance with Section 404 of the Clean Water Act for storm water runoff control measures.

The Eccles alternative segment Interchange Yard would require portions of Clover Creek to be filled to elevate the site out of the floodplain. For a length of approximately 1,400 meters (4,600 feet) along the bed of this ephemeral creek (for construction of the interchange tracks), the fill would extend approximately 7.6 to 15 meters (25 to 50 feet) into the creek bed. For a length of approximately 900 meters (2,900 feet) on the east end and 600 meters (2,000 feet) on the west end of the interchange tracks, (for construction of the interchange siding), the fill would extend approximately 8 meters (25 feet) into the creek. The total area that would be filled within the confines of Clover Creek would be approximately 0.033 square kilometer (8.2 acres).

Along the Mina rail alignment, there could be temporary impacts from disturbance of about 2,000 square meters (0.55 acre) of wetlands along Schurz alternative segments 1 and 4, and 3,000 square meters (0.73 acre) of wetlands along Schurz alternative segments 5 and 6 during construction of a bridge at the rail line crossing of the Walker River. Permanent fill or loss of wetlands would total about 20 square meters (0.005 acre) for emplacement of about 10 piers in wetlands for Schurz alternative segments 1 and 4, or 28 square meters (0.007 acre) for emplacement of about 14 piers for Schurz alternative segments 5 and 6.

While some changes would be unavoidable, DOE would take steps to ensure the alterations to natural drainage, sedimentation, and erosion processes would not increase future flood damage, increase the impact of floods on human health and safety, or cause identifiable harm to the function and values of floodplains. The Department would implement best management practices, including erosion control measures such as the use of silt fences and flow-control devices to reduce flow velocities and minimize erosion.

6.4.1.6 Groundwater Resources

The generally dry climate characterizing the southern Nevada region is consistent with a lack of shallow groundwater underlying much of the length of the Caliente and Mina rail alignments. The region of influence for groundwater resources includes portions of the aquifers that would be affected by groundwater withdrawals DOE would make to obtain the water needed for railroad construction and operations. Groundwater resource features evaluated through impacts analysis include existing wells and nearby springs. In the Caliente rail alignment region of influence, groundwater withdrawals for irrigation and agricultural purposes currently represent most of the groundwater usage. In the Mina rail alignment region of influence, public supply-municipal, stock watering, and mining uses currently represent most of the groundwater usage.

To supply the approximately 7.5 billion cubic meters (6,100 acre-feet) of water needed during the construction phase along the Caliente rail alignment, DOE estimates that it would need to install approximately 150 to 176 new wells. To supply the approximately 7.4 billion cubic meters (5,950 acre-feet) of water needed during the construction phase along the Mina rail alignment, DOE estimates that it would need to install between approximately 77 and 110 new wells.

DOE analyses indicated that the effects of groundwater withdrawals from the proposed water-supply wells at the range of production rates that could be required to support a 4-year construction phase along either rail alignment would be localized in nature and extent, and hydrogeologic effects would be temporary. DOE determined that the short-term impacts caused by water withdrawals would be a series of localized drawdown cones of depression within the host aquifer surrounding each pumped well. DOE does not anticipate that proposed groundwater withdrawals would conflict with known regional or local aquifer management plans or the goals of governmental water authorities, and impacts from groundwater withdrawals on downgradient groundwater basins (or hydrographic areas) would tend to be small.

Groundwater withdrawals from hydrographic basin 227A, where the regions of influence for the railroad and repository overlap, would be approximately 430,000 cubic meters (350 acre-feet) during the first year of construction, 210,000 cubic meters (172 acre-feet) during the second year, 37,000 cubic meters (30 acre-feet) during the third year, and 25,000 cubic meters (20 acre-feet) during the final year of construction. Groundwater withdrawal rates for permanent water wells to support rail sidings and railroad operations facilities would be very low [less than 4 liters (1 gallon) per minute of the permanent water wells to approximately 26 liters (7 gallons) per minute]. Groundwater withdrawals from hydrographic basin 227A during operations of the railroad would be approximately 7,400 cubic meters (6 acre-feet) per year, and would commence about 1 year after repository construction began.

Overall, water demands for railroad construction and operations along the Caliente or the Mina rail alignment would represent a small portion of current water use amounts in their respective regions of influence, which would likely continue to be dominated by irrigation and agricultural withdrawals, with possibly increasing urban use from water transfers to the Las Vegas area. DOE determined that impacts to ground subsidence or groundwater quality that could result from railroad construction and operations along either rail alignment would be small.

Under the Shared-Use Option for either rail alignment, commercial-only facilities would require water for daily operation. The additional impacts to groundwater resources would be small, and overall would be similar to those described for the Proposed Action without shared use.

6.4.1.7 Biological Resources

DOE considered two areas of assessment in analyzing the affected environment for biological resources: a region of influence consisting of the nominal width of the construction right-of-way and a larger study area consisting of a 16-kilometer (10-mile)-wide area extending 8 kilometers (5 miles) on either side of the centerline of the rail alignment to ensure the identification of sensitive habitat areas and transient or migratory wildlife. The Caliente and Mina rail alignments are situated within the "cold" Great Basin Desert that covers most of central and northern Nevada and the "hot" Mojave Desert that covers most of southern Nevada and much of southeastern California. Although the two deserts are distinguished climatically, they are also distinguished by their predominant vegetation and vegetation communities.

For both the Caliente rail alignment and the Mina rail alignment, DOE determined that there would be some indirect adverse impacts due to the potential for the introduction and spread of noxious and invasive weed species during construction activities; however, the Department would minimize or avoid impacts through implementation of best management practices and Bureau of Land Management-prescribed methods. DOE concluded that there would be a small mostly short-term indirect impact to game species during railroad construction and operations along either rail alignment, due to temporary displacement causing pressure on other areas for habitat and forage. There could be small direct impacts due to a small loss of forage from the removal of vegetation to construct the proposed railroad. In addition, railroad operations could result in possible wildlife collisions with trains and disturbance from noise caused by passing trains. However, these impacts would not impact the viability of any game species' population.

DOE determined that federally listed species potentially present along the Caliente and Mina rail alignments could include the Mojave population of the desert tortoise, the southwestern willow flycatcher, the yellow-billed cuckoo, the Lahontan cutthroat trout, and the Ute ladies' tresses orchid. There would likely be small short-term indirect impacts to some Bureau of Land Management and State of Nevada special-status animal species because they might avoid the area of the rail alignment or be displaced during construction activities. Any potential direct impact would be due to habitat fragmentation and disturbance and possible injury or loss of individuals of a species from collision with trains. There could be indirect impacts on small mammals as a result of possible changes to predator-prey interactions due to the construction of towers and other structures that would provide new perch habitat for raptors and other predatory birds. DOE determined that potential impacts from noise disturbance to migratory birds would be small and short-term during construction and small from permanent habitat loss during the operations. Potential direct impacts to the desert tortoise would be due to fragmentation of habitat and the possible crushing of occupied burrows during construction of common segment 6 and the Rail Equipment Maintenance Yard. Although these losses would be a small decrease in the number if individual tortoises in the vicinity of the railroad, long-term survival of this species would not be affected. For both the Caliente rail alignment and Mina rail alignment DOE determined that impacts to herd management areas and potential impacts to individual wild horses or burros would be small and would not significantly affect the management strategies utilized within the herd management areas.

DOE anticipates that for the Caliente rail alignment there would be short-term and long-term impacts to wetlands and riparian habitats from construction of the Caliente alternative segment and either of the potential Staging Yard locations (Indian Cove and Upland), and the Eccles alternative segment. Impacts from constructing the Caliente alternative segment would be mostly short-term and small, because the rail line would be constructed over an abandoned rail roadbed and limited to existing bridge crossings that would require modifications. The Eccles alternative segment would result in a small short-term impact to riparian habitat and limited to bridge construction over Meadow Valley Wash. Construction of the Indian Cove Staging Yard could result in a moderate impact compared to the Upland Option due to topographic constraints that could require possible draining and filling of the wetland. The proposed Eccles Interchange Yard could result in mostly small direct short-term impacts due to a small loss of riparian vegetation; and small short-term indirect impacts with the potential for change in stream flow and increase in sedimentation. DOE determined there would be a moderate impact to wildlife habitat along Garden Valley alternative segments 1 and 3. Localized and minor loss of roosting and foraging habitat for the southwestern willow flycatcher and western yellow-billed cuckoo could occur from construction of the Caliente alternative segment; however, because these species do not nest along the alignment, impacts would be small and limited to transient individuals.

DOE determined that for the Mina rail alignment there would be direct short-term impacts to riparian vegetation from construction of Schurz alternative segment 1, 4, 5, or 6 due to bridge construction over the Walker River. There would be no long-term impacts on riparian vegetation along the Walker River as a result of constructing any of the Schurz alternative segments. There would be short-term moderate impacts to wildlife habitat at the potential Malpais Mesa quarry site. Construction of the Walker River Bridge for the Schurz alternative segment 1, 4, 5, or 6 could result in a moderate short-term indirect impact on Lahontan cutthroat trout; however, DOE could mitigate any anticipated impact.

Under the Shared-Use Option, there would be more train traffic; therefore, DOE anticipates wildlife interactions with train traffic (collisions, change in movement patterns, altered behavior, and nest abandonment) would be slightly increased. Nevertheless, DOE anticipates that this slight increase in train traffic would result in small impacts to the wildlife communities. The existing rail alignment design could accommodate shared use with little additional construction (a few sidings) and the Department does not anticipate any other additional impacts above those discussed.

6.4.1.8 Cultural Resources

The region of influence for cultural resources includes the construction right-of-way (the area of potential direct and indirect impacts) and a 3.2-kilometer (2-mile)-wide area centered on the rail alignment (the area of potential indirect impacts).

Because of the length of the proposed rail line along the Caliente and Mina rail alignments, DOE is using a phased cultural resource identification and evaluation approach, described in 36 CFR 800.4(b)2, to identify specific cultural resources. Under this approach, DOE would defer final intensive field surveys (known as a Class III inventory) of the actual construction right-of-way, as provided in the Programmatic Agreement between DOE, the Bureau of Land Management, the Surface Transportation Board, and the Nevada State Historic Preservation Office. The Programmatic Agreement states that an appropriate level of field investigation—including on-the-ground intensive surveys; evaluations of all recorded resources listed on the *National Register of Historic Places*; assessments of adverse effects; and applicable mitigation of identified impacts—be completed before any ground-disturbing construction activities that could impact a specific resource could begin.

Railroad construction and operations could lead to unavoidable changes in cultural landscapes, such as changes to ethnographic, rural historic and historic viewscapes. Cultural landscapes along the Caliente rail alignment include historic-period Western Shoshone villages and surrounding use areas in the Oasis Valley, the Goldfield area, and Stone Cabin and Reveille Valleys; early ranching operations in Stone Cabin and Reveille Valleys; the historic Mormon settlement of Meadow Valley Wash; and the Goldfield, Clifford, and Reveille Mining Districts. Cultural landscapes along the Mina rail alignment include historic period Northern Paiute use of the Walker River and Walker Lake areas, historic period Western Shoshone villages and surrounding use areas in the Oasis Valley and Goldfield areas, and historic mining in the Luning, Mina, and Goldfield districts.

DOE completed literature reviews and a Class II inventory (sample field surveys within the construction right-of-way) for 20 percent of each alternative segment and common segment along the Caliente and Mina rail alignments and has thereby identified potential areas of specific impacts. In addition, DOE conducted an intensive Class III inventory along a 12-kilometer (7.4-mile) corridor within the Yucca Mountain site boundary, which resulted in the identification of seven sites and five isolates (isolated artifacts).

Based on preliminary information and the sample surveys conducted to date, the magnitude of impacts along both the Caliente and Mina rail alignments would range from small to moderate due to the extensive effort DOE would undertake to avoid or mitigate impacts to cultural resources in accordance with the regulatory framework and with the terms of the cultural resources Programmatic Agreement.

Impacts to cultural resources under the Shared-Use Option for either the Caliente or Mina rail alignment would be approximately the same as those under the Proposed Action without shared use. However, construction of any additional commercial-use sidings would have the potential to impact cultural resources.

6.4.1.9 American Indian Interests

Based on information provided by the Consolidated Group of Tribes and Organizations, American Indians are concerned that substantial and high adverse effects to a number of American Indian interests could be caused within and adjacent to the Caliente rail alignment region of influence which also encompasses the southern segments of the Mina rail alignment. The Consolidated Group of Tribes and Organizations is a forum consisting of officially appointed tribal representatives, from 17 tribes and organizations, who are responsible for presenting their respective tribal concerns and perspectives to DOE. At the time of discussions with the Consolidated Group of Tribes and Organizations, the Mina rail alignment was not under consideration as an implementing alternative and the views of the Northern Paiute peoples who traditionally occupied lands north of Goldfield and Tonopah are not presented by this group. As part of any Proposed Action, the Department would continue to consult with American Indian tribes with regard to their interests and beliefs.

The proposed Mina rail alignment would pass through and directly affect the Walker River Paiute Reservation. In a letter dated April 29, 2007, the Walker River Paiute Tribal Council officially informed the Department of their withdrawal from the environmental impact statement process. The Tribal Council made the decision to withdraw based on information obtained during the Tribe's involvement with the Rail Alignment EIS process and input from Tribal members. The Tribe determined that the impacts and risks associated with nuclear shipments through the Reservation were too great and they reaffirmed a past objection to the transportation by any means of nuclear or radioactive material through the Reservation.

American Indian views on construction and operation of a railroad along the Caliente rail alignment, as primarily expressed by the Consolidated Group of Tribes and Organizations, state that construction and operation of the proposed railroad would constitute an intrusion on the traditional lands of Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people; would disturb cultural, biological, botanical, geological, and hydrological resources, including American Indian viewscapes, songscapes, storyscapes, and traditional cultural properties; would restrict the free access of American Indian people to their resources; and could cause substantial and high adverse effects to a number of American Indian interests within and adjacent to the region of influence. Within that forum of beliefs there would be an unavoidable impact to American Indian interests.

6.4.1.10 Socioeconomics

DOE assessed impacts to socioeconomic conditions in relation to population, housing, employment and income, and public service over the region of influence for the Caliente rail alignment in Lincoln, Esmeralda, Nye, and Clark Counties, and over the region of influence for the Mina rail alignment in Churchill, Lyon, Mineral, Nye, Esmeralda, and Clark Counties, the combined area of Washoe County and Carson City, and the Walker River Paiute Reservation.

The social and economic activities and changes associated with railroad construction along either rail alignment would include a brief elevation in project-related employment; increases in real disposable income; increases in state and local spending; increases in Gross Regional Product; population increases, slower rate of growth in the level of employment as railroad project activities moved from construction to operations; and possible small stresses on transportation, including small traffic-delay impacts on road traffic at grade crossings. The percentage values of such changes would be low, as listed in Chapter 2, Table 2-3, and DOE has assessed such impacts to be generally small.

Changes associated with the railroad operations along either alignment would include increases in project-related employment (particularly associated with railroad facilities); slight population increases; possible small stresses on transportation, including small traffic-delay impacts on road traffic at grade crossings; some pressure on housing; and possible strains on public services (schools, health care, fire protection) in southern Nye County where the Cask Maintenance Facility, Rail Equipment Maintenance Yard, train crew quarters, and possibly the Railroad Control Center and the National Transportation Operations Center would be located. The percentage values of such changes would be low, as shown in Chapter 2, Table 2-3. DOE has assessed such impacts to be generally small to moderate.

Under the Shared-Use Option for either rail alignment, there would be little increase in impacts beyond those described for the Proposed Action without shared use. Based on the lengths of track involved under the Shared-Use Option, the incremental impacts to traffic from constructing the additional sidings would be a small fraction of the overall impacts for rail line construction under the Proposed Action without shared use. Thus, impacts to the transportation infrastructure under the Shared-Use Option would be small. Traffic-delay impacts at highway-rail grade crossings from construction trains would be consistent with the delay impacts under the Proposed Action without shared use. These impacts would be small.

6.4.1.11 Occupational and Public Health and Safety

6.4.1.11.1 *Caliente and Mina Rail Corridors*

Nonradiological Occupational Health and Safety Impacts

DOE estimated nonradiological occupational health and safety impacts in relation to worker exposures to physical hazards and nonradioactive hazardous chemicals during the construction phase. DOE based these estimates on the number of hours worked and occupational incident rates for total recordable cases, lost workday cases, and fatalities.

Construction and operation workers could be exposed to physical hazards and to nonradiological hazardous chemicals related to operation and maintenance of construction equipment, rail line equipment, and facility equipment, including maintenance of casks and maintenance-of-way activities, which would include welding, metal degreasing, painting, and related activities. Occupational health and safety impacts could also result from worker exposure to fuels, lubricants, and other materials used in railroad construction, operation, and maintenance.

The recorded incident rates of these exposure hazards during construction work at the Yucca Mountain site have been small and are anticipated to be small for railroad construction and operations. Dust and soils hazards include potential occupational exposure to hazardous inhalable dust. However, occupational impacts associated with exposure to dust would be expected to be small. DOE would implement measures, such as processing and engineering controls, to reduce exposure to dust. Impacts to construction or operations workers from unexploded ordnance would be small due to implementation of inspection procedures and mitigation measures. Workers might also be exposed to biological hazards including infectious diseases (such as Hantavirus or West Nile Virus) and other biological hazards (such as venomous animals). The recorded incidence rates of these biological hazards are small, and DOE would expect small impacts to construction or operations workers from these biological hazards.

DOE used both qualitative and quantitative components to estimate transportation accident incidents and potential fatalities resulting from vehicular and train accidents.

DOE estimated the following:

- During the construction phase, along both the Caliente rail alignment and the Mina rail alignment, there would be 6 vehicular-related fatalities.

- During the operations phase along the Caliente rail alignment, there would be 8 vehicular-related fatalities; along the Mina rail alignment, there would be seven vehicular-related fatalities.

- During railroad construction and operations along the Caliente rail alignment and the Mina rail alignment, modeling indicates that there would be 16 rail-related accidents and approximately 1 rail-related fatality.

- Nonradiological fatality impacts to workers from industrial hazards from railroad and facility construction and operations along the Caliente rail alignment would be approximately 3, and for the Mina rail alignment would be approximately 2.

For the Shared-Use Option, DOE estimated the following:

- During the operations phase along the Caliente rail alignment, there would be eight vehicular-related fatalities; along the Mina rail alignment, there would be 7 vehicular-related fatalities.

- During the operations phase along the Caliente rail alignment, there would be 26 rail-related accidents and 4 rail-related fatalities; along the Mina rail alignment, there would be 36 rail-related accidents and 7 rail-related fatalities.

Radiological Occupational Health and Safety Impacts

DOE estimated radiological impacts to workers and the public for incident-free transportation, the risk from transportation accidents, and the consequences of severe transportation accidents. The region of influence for radiological impacts to members of the public during incident-free transportation includes the area 0.8 kilometer (0.5 mile) on either side of the centerline of the rail alignments. The region of influence for occupational radiological impacts during incident-free operation includes the physical boundaries of railroad operations support facilities. For radiological accidents, the populations within the region of influence are based on the population within 80 kilometers (50 miles) on either side of the centerlines of the rail alignments.

DOE estimated the following:

- For workers, the radiological impacts were estimated to be 0.34 latent cancer fatality for the Caliente rail alignment and 0.35 latent cancer fatality for the Mina rail alignment.

- For workers at the Cask Maintenance Facility, the radiological impacts were estimated to be 0.43 latent cancer fatality. For workers at the Rail Equipment Maintenance Yard, the radiological impacts were estimated to be 0.0096 latent cancer fatality.

- For members of the public, the radiological impacts were estimated to be 1.4×10^{-4} latent cancer fatality for the Caliente rail corridor and 8.5×10^{-4} latent cancer fatality for the Mina rail alignment.

- For members of the public, the radiological impacts from the Cask Maintenance Facility were estimated to be 7.0×10^{-6} latent cancer fatality.

- The risk from transportation accidents was estimated to be 1.3×10^{-6} latent cancer fatality for the Caliente rail alignment and 7.7×10^{-6} latent cancer fatality for the Mina rail alignment.

- The consequences of the maximum reasonably foreseeable accident were estimated to be 0.0012 latent cancer fatality in rural areas and 0.46 latent cancer fatality in suburban areas along the Caliente rail alignment, and 0.0089 latent cancer fatality in rural areas and 1.2 latent cancer fatalities in suburban areas along the Mina rail alignment. The frequency of this severe accident ranged from 6×10^{-7} to 7×10^{-7} per year.

Sabotage

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the United States Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements intended to prevent terrorists from gaining control of commercial aircraft and additional measures imposed on foreign passenger carriers and domestic and foreign cargo carriers, as well as charter aircraft.

The Federal Government has also greatly improved the sharing of intelligence information and the coordination of response actions among federal, state, and local agencies. DOE has been an active participant in these efforts. In addition to its domestic efforts, DOE is a member of the International Working Group on Sabotage for Transport and Storage Casks, which is investigating the consequences of sabotage events and exploring opportunities to enhance the physical protection of casks.

The Department, as required by the *Nuclear Waste Policy Act*, would use shipping casks certified by the NRC. Spent nuclear fuel is protected by the robust metal structure of the shipping cask, and by cladding that surrounds the fuel pellets in each fuel rod of an assembly. Further, the fuel is in a solid form, which would tend to reduce dispersion of radioactive particulates beyond the immediate vicinity of the cask, even if a sabotage event were to result in a breach of the multiple layers of protection.

In addition, the NRC has promulgated rules (10 CFR 73.37) and interim compensatory measures (67 FR 63167, October 10, 2002) specifically to protect the public from harm that could result from sabotage of spent nuclear fuel casks. The Department has committed to following these rules and measures (see 69 FR 18557, April 8, 2004).

For the reasons stated above, DOE believes that under general credible threat conditions the probability of a sabotage event that would result in a major radiological release would be low. Nevertheless, because of the uncertainty inherent in the assessment of the likelihood of a sabotage event, DOE has evaluated events in which a military jet or commercial airliner would crash into a spent nuclear fuel cask or a modern weapon (a high energy density device) would penetrate a spent nuclear fuel cask.

In the Yucca Mountain FEIS (Appendix J, Section J.3.3.1), DOE evaluated the ability of large aircraft parts to penetrate shipping casks and found that that neither the engines nor shafts would penetrate a cask and cause a release of radiological materials if an aircraft were to crash into a spent nuclear fuel cask. For the Rail Alignment EIS, DOE obtained more recent estimates of the fraction of spent nuclear fuel materials that would be released (release fractions) (DIRS 104918-Luna et al. 1999, all). Based on the more recent information DOE estimated that there would be 0.0028 latent cancer fatalities in rural areas and 1.1 latent cancer fatalities in suburban areas along the Caliente rail alignment, and 0.021 latent cancer fatalities in rural areas and 2.8 latent cancer fatalities in suburban areas along the Mina rail alignment.

In addition to analyzing the impacts of sabotage events, the Department would continue to modify its approach to ensuring safe and secure shipments of spent nuclear fuel and high-level radioactive waste between now and the time of shipments.

DOE also used both qualitative and quantitative components to estimate transportation accident incidents and potential fatalities resulting from vehicular and train accidents.

6.4.1.11.2 *Other Nevada Transportation Impacts*

In addition to the impacts from constructing, operating, and closing a rail line within Nevada, there would also be transportation-related impacts from truck shipments of spent nuclear fuel and high-level radioactive waste within Nevada. For these shipments, DOE estimated the following:

- The number of latent cancer fatalities to workers from radiological impacts during the operations period would be 0.057 (about 1 chance in 20).
- The number of latent cancer fatalities to the public from radiological impacts during the operations period would be 0.012 (about 1 chance in 80).
- The number of fatalities from exposure to vehicle emissions would be 0.0046 (about 1 chance in 200).
- The radiological risk from transportation accidents would be 1.9×10^{-6} latent cancer fatality (about 1 chance in 500,000).
- The number of nonradiological traffic fatalities would be 0.050 (about 1 chance in 20).
- The total number of radiological and nonradiological fatalities from truck shipments of spent nuclear fuel and high-level radioactive waste within Nevada would be 0.12 (about 1 chance in 8).

Within Nevada, there would also be transportation-related impacts from rail shipments from the Nevada border to the beginning of the Caliente or Mina rail corridors. These impacts are not included in the estimates of impacts for the Caliente and Mina rail corridors but are included in the national impacts presented in Section 6.3 of this Repository SEIS.

Table 6-15 lists the impacts for maximally exposed workers and members of the public from transporting spent nuclear fuel and high-level radioactive waste in Nevada for both rail and truck shipments. Among workers, escorts and inspectors would receive the highest estimated radiation doses, in large part because of their proximity to casks and the amount of time they are exposed. The maximally exposed worker would receive an estimated radiation dose of 25 rem over as many as 50 years of repository operations, based on a 500 millirem per year administrative dose limit (DIRS 174942-BSC 2005, Section 4.9.3.3). The probability of a latent cancer fatality for this worker is 0.015 or about 1 chance in 70.

Members of the public would receive lower estimated radiation doses than workers from incident-free transportation because they would not be as close to the casks as workers and would not be exposed for as long as workers. The member of the public with the highest estimated individual radiation dose would be a service station attendant who refueled the trucks during shipments of spent nuclear fuel and high-level radioactive waste. Using assumptions that tend to overstate the risks, the same person would refuel about 600 trucks and receive an estimated radiation dose of 0.21 rem over as many as 50 years of shipments. Using these assumptions, the probability of a latent cancer fatality for this individual is 0.00013, or about 1 chance in 8,000.

Table 6-15. Estimated radiation doses for maximally exposed workers and members of the public from Nevada transportation.[a]

Category	Dose (rem)	Probability of LCFs
Workers		
Escort	25[b]	0.015
Rail worker	25[b]	0.015
Railyard crew member	4.8	0.0029
Truck inspector	11	0.0065
Worker at maintenance-of-way trackside facility	0.00088	0.00000053
Worker located at siding	0.00013 – 0.00051	0.000000077 – 0.00000030
Public		
Resident along rail route	0.0078	0.0000047
Other individuals near the rail route in Las Vegas[c]		
Individual at 15 meters	0.00075	0.00000045
Individual at 20 meters	0.00055	0.00000033
Individual at 30 meters	0.00035	0.00000021
Individual at 35 meters	0.00029	0.00000018
Individual at 40 meters	0.00024	0.00000015
Individual at 100 meters	0.000067	0.000000040
Individual at 160 meters	0.000029	0.000000017
Other individuals near the rail route in Reno (Reno trench)		
Individual along U.S. 95 in Indian Springs	0.0049	0.0000029
Person in traffic jam	0.0011	0.00000064
Person at service station	0.016	0.0000096
Person near staging yard	0.21	0.00013
Caliente-Indian Cove	0.0000030	0.0000000018
Caliente-Upland	0.0027	0.0000016
Eccles-North	0.0000034	0.0000000021
Mina-Hawthorne	0.00018	0.00000011

a. Impacts are for the entire 50-year shipping period.
b. Based on a 0.5-rem-per-year administrative dose limit.
c. Locations identified by the Nevada Agency for Nuclear Projects (DIRS 158452-Nevada Agency for Nuclear Projects 2002, p. 123).
LCF = Latent cancer fatality.

The impacts of severe transportation accidents involving rail shipments of spent nuclear fuel and high-level radioactive waste within Nevada would be similar to the impacts estimated in Section 6.3.3.2 of this Repository SEIS and in Sections 4.2.10 and 4.3.10 of the Rail Alignment EIS. The impacts of severe transportation accidents involving truck shipments of spent nuclear fuel and high-level radioactive waste within Nevada would be less than those involving rail shipments. In addition, the impacts of transportation sabotage events involving truck and rail shipments of spent nuclear fuel and high-level radioactive waste would be similar to the impacts estimated in Section 6.3.4 of this Repository SEIS and in Sections 4.2.10 and 4.3.10 of the Rail Alignment EIS.

6.4.1.12 Noise and Vibration

DOE analyzed potential impacts from noise based on current ambient noise levels, noise modeling for future activities (proposed railroad construction and operations), and identification of changes in noise levels at receptors within the regions of influence. The region of influence for noise and vibration for construction and operations of the railroad along either the Caliente or the Mina rail alignment includes the construction right-of-way and extends out to variable distances along each rail alignment (depending on several factors, including the number of trains per day, ambient noise level, train speed, and number of rail cars).

For operation of trains during the construction and operations phases, DOE analyzed noise impacts under established Surface Transportation Board criteria (a noise level of 65-dBA day-night average sound level or greater, with a 3-dBA or greater increase from the baseline). For noise impacts from construction activities, DOE used U.S. Department of Transportation, Federal Transit Administration, methods and construction noise guidelines. To evaluate potential vibration impacts from construction and operation activities, DOE used Federal Transit Administration building vibration damage and human annoyance criteria.

DOE determined that railroad construction and operations along the Caliente rail alignment would lead to an unavoidable increase in ambient noise from construction activities and passing trains. Noise from trains might be noticeable as new noise in residential areas near the rail line in Caliente and Goldfield. Because there is already a substantial amount of train activity in Caliente, additional train noise would be less noticeable than in other areas where there is currently no train activity and no train noise. For construction activities, noise levels in Caliente would be higher than Federal Transit Administration construction noise guidelines and would result in a temporary unavoidable impact. Train noise during the construction and operations phases would not cause adverse noise impacts because noise levels at receptors would be lower than Surface Transportation Board adverse impact criteria.

DOE determined that railroad construction and operations along the Mina rail alignment could lead to an unavoidable increase in ambient noise from passing trains in areas of Nevada that are mostly uninhabited. Noise from trains might be noticeable as new noise in residential areas near the rail line in Silver Springs, Silver Peak, Mina, and Goldfield. Because there is already some train activity in Silver Springs, additional train noise would be less noticeable there than in other areas where there is currently no train activity and no train noise. Construction of any of the Schurz alternative segments would eliminate future noise and vibration associated with operation of the existing Department of Defense Branchline through Schurz. However, there would be construction noise associated with removal of this existing rail line, although this noise would be temporary and no adverse impact would be expected.

For construction activities, noise levels along the Mina rail alignment would be lower than Federal Transit Administration construction noise guidelines. For train noise during the construction phase, there would be temporary adverse impacts at receptors in Silver Springs. For train noise during the operations phase, estimated noise levels at eight receptors in Silver Springs and one in Wabuska would be higher than impact criteria; therefore, there would be adverse impacts from noise associated with railroad operations at those locations. However, DOE would investigate mitigation methods for these nine locations. Mitigation methods, where reasonable and feasible, could include building sound insulation or the development of a Quiet Zone.

During the construction and operations phases along either the Caliente or Mina rail alignment, vibration levels would not exceed the Federal Transit Administration damage criteria for extremely fragile historic buildings. Therefore, DOE would expect no building damage due to vibration. In addition, train-generated vibration levels would be lower than Federal Transit Administration human annoyance criterion.

Under the Shared-Use Option for either rail alignment, increased rail traffic could result in noise impacts similar to the impacts described for the Caliente and Mina rail alignments without shared-use. Increased operations would not affect vibration impacts because vibration is evaluated on a maximum-level basis only.

6.4.1.13 Aesthetic Resources

DOE considered the region of influence for the aesthetic resources as the viewshed around all common segments, alternative segments, and facilities along the Caliente and Mina rail alignments. To ensure that seldom-seen views were included in this analysis, DOE used a conservative region of influence extending 40 kilometers (25 miles) on either side of the centerline of all common segments and alternative segments, and around facilities. Most lands the Proposed Action would affect are Bureau of Land Management-administered public lands, including those on which the proposed railroad would be constructed. For this reason, DOE used Bureau of Land Management visual resource management classifications and contrast rating methodologies to evaluate aesthetic impacts to the surrounding viewshed. The Bureau of Land Management assigns visual resource management classes to lands under its jurisdiction, based on scenic quality and other factors, that range from Class I to Class IV, with Class I representing the highest visual values. Each class comes with specific visual resource management objectives that indicate the levels of project-related contrast that are acceptable. In this analysis, the primary basis for identifying potential adverse impacts to aesthetic resources was inconsistency with these Bureau of Land Management visual resource management objectives. The Department assessed the potential visual contrast between existing conditions and conditions expected during the project from key locations and compared these levels of contrast with the visual resource management objectives associated with the Bureau of Land Management classifications of the surrounding viewshed.

Along both the Caliente and the Mina rail alignments, DOE found that the contrast that would be caused by the rail line and support facilities would remain consistent with Bureau of Land Management visual resource management objectives during the operations phase, but could be inconsistent in certain locations during the construction phase. Along the Caliente rail alignment, a conveyor crossing of U.S. Highway 93 near the Caliente-Indian Cove location of the Staging Yard and along some portions of Garden Valley alternative segments 1, 2, 3, and 8, construction would temporarily not meet Bureau of Land Management visual resource management objectives for Class II areas.

Along the Mina rail alignment, DOE determined that construction of Schurz alternative segment 6 crossing of U.S. Highway 95 on the Walker River Paiute Reservation would temporarily not meet Bureau of Land Management objectives for Class III areas.

Overall, DOE anticipates that short-term visual impacts during the construction phase would range from small to large, and long-term impacts during the operations phase would range from small to moderate and would be consistent with applicable Bureau of Land Management visual resource management objectives.

Impacts to aesthetic resources during the construction phase under the Shared-Use Option would generally be the same as those under the Proposed Action without shared use. Construction of additional sidings would create small impacts to the visual setting because of the short duration of construction. Impacts to aesthetic resources during the construction phase under the Shared-Use Option for both the Caliente and Mina rail alignments would be generally the same as those under the Proposed Action without shared use. Construction of additional sidings would create small impacts to the visual setting because of the short duration of construction.

6.4.1.14 Utilities, Energy, and Materials

The Caliente rail alignment region of influence for public water systems and wastewater transported offsite for treatment and disposal is Lincoln, Nye, and Esmeralda Counties. The Mina rail alignment region of influence for public water systems and wastewater transported offsite for treatment and disposal is Lyon, Mineral, Esmeralda, and Nye Counties, and the Walker River Paiute Reservation, the bulk of which lies in Mineral County with smaller portions in Churchill and Lyon Counties. The region of influence for telecommunications and electricity is limited to the companies that service the aforementioned counties. The region of influence for fossil fuels is limited to regional suppliers within the State of Nevada. The region of influence for construction materials is defined by the distribution networks and suppliers of that material to the general project area.

DOE determined that the demands placed on utilities, energy, and materials from constructing and operating the proposed rail line along either alignment would be met by existing supply capacities; therefore, potential impacts would be small. Utility interfaces would have the potential for short-term interruption of service, but would experience no permanent or long-term loss of service or prevention of future service-area expansions. Most water for construction along either rail alignment would be supplied by new wells, although public water systems could be slightly affected by population increases attributable to construction employees. Wastewater treatment systems would not be directly affected directly by construction activities, because dedicated treatment systems would be provided at construction camps; however, there could be small impacts to wastewater treatment systems due to population increases attributable to construction employees. There would be very small impacts to telecommunications systems because, during the construction phase, DOE would utilize a dedicated telecommunications system and rely little on existing telecommunications systems.

Peak electricity demand would be within capacity of regional providers. The demand for fossil fuels during construction would be approximately 6.5 percent and 6 percent of statewide use for the Caliente and Mina rail alignments, respectively, and could be met by existing regional supply systems and suppliers. During the operations phase, the demand for fossil fuels for either rail alignment would be less than 0.25 percent of statewide use. The primary materials that would be consumed during the construction phase would be steel; concrete, principally for rail ties, bridges, and drainage structures; and rock for ballast and subballast. DOE determined that construction material requirements for the Caliente rail alignment and for the Mina rail alignment would be a small fraction of current production rates within the respective regions of influence.

Under the Shared-Use Option for either rail alignment, the incremental demands on utilities, energy, and materials for construction of commercial sidings and support facilities would be sufficiently small that the anticipated impacts on these resources would be effectively the same as those for the Proposed Action without shared use. Therefore, potential impacts to local, regional, or national suppliers of such resources under the Shared-Use Option along either rail alignment would be small.

Fossil-fuel requirements for transporting general freight under the Shared-Use Option would depend on the volume and distance of shared-use traffic. DOE estimated that the incremental annual diesel consumption for commercial shared-use traffic would be 5.5 million liters (1.5 million gallons), a rate that is less than 0.3 percent of current annual diesel fuel usage in Nevada. Most, if not all, of this fuel consumption would be offset by diesel fuel that would otherwise be used if the goods or materials were shipped by truck. Therefore, the impact to the capacities of national and regional fuel producers and distributors under the Shared-Use Option would be small.

6.4.1.15 Hazardous Materials and Wastes

For both the Caliente and Mina rail alignments, the region of influence for the use of hazardous materials and the generation of hazardous and nonhazardous wastes includes the nominal width of the rail line construction right-of-way, and the locations of railroad construction and operations support facilities; for the disposal of hazardous wastes, it includes the entire continental United States (commercial hazardous waste disposal vendors could utilize facilities throughout the country); and for the disposal of low-level radioactive wastes, it includes DOE low-level waste disposal sites, sites in Agreement States, and NRC-licensed sites. The region of influence for the disposal of nonhazardous waste for the Caliente rail alignment includes the disposal facilities in Lincoln, Nye, Esmeralda, and Clark Counties; and for the Mina rail alignment includes the disposal facilities in Mineral, Nye, Esmeralda, and Clark Counties.

During railroad construction and operations, DOE would store and use hazardous materials such as oil, gasoline, diesel fuel, and solvents, primarily for the operation, maintenance, and cleaning of equipment and facilities, which would result in the generation of associated hazardous wastes. During the railroad construction and operations phases, the Department would implement an Environmental Management System and a Pollution Prevention/Waste Minimization Program, which would include an evaluation of methods to eliminate, reduce, or minimize the amounts of hazardous materials used and hazardous wastes generated. Ample disposal capacity is available for the disposal of hazardous waste during the construction and operation phases. DOE would implement appropriate planning measures for the storage and handling of hazardous materials and comply with applicable regulations.

DOE would dispose of non-recyclable or non-reusable waste in permitted landfills. During construction it is likely that, if utilized, some of the larger landfills would not see an appreciable change in the amount of waste received; however, some of the smaller landfills, if utilized, might see a substantial, although manageable, change in daily receipt of solid, industrial, and special wastes.

DOE estimates that railroad construction along the Caliente rail alignment would increase the overall rate of disposal of solid waste by about 0.01 percent and industrial and special waste in the region of influence by about 0.261 percent. DOE anticipates that impacts to local landfills from the disposal of solid and industrial and special wastes would be small (for the relatively large Apex Landfill) to moderate (for the smaller landfills such as Goldfield Class I).

DOE estimates that railroad construction along the Mina rail alignment could generate three times the amount of industrial and special waste as would railroad construction along the Caliente rail alignment. This is because of wastes from dismantling the Department of Defense Branchline through the town of Schurz. However, to the extent practicable, these wastes would be recycled to minimize waste volumes. DOE estimates that railroad construction along the Mina rail alignment would increase the overall rate of disposal of solid waste by 0.077 percent and industrial and special waste in the region of influence by about 0.41 percent and 9 percent, respectively. DOE anticipates that impacts to local landfills from the disposal of solid and industrial and special wastes would be small (for the relatively large Apex Landfill) to moderate (for the smaller landfills such as Goldfield Class I).

During railroad operations along either the Caliente or Mina rail alignment, the generation of wastes would be substantially less than during the construction phase. DOE anticipates railroad operations along either alignment would produce similar amounts of wastes. Therefore, impacts to landfills during operations would be small because ample disposal capacity would be available for either rail alignment.

Activities at the Cask Maintenance Facility would generate from 3,200 to 7,900 cubic meters (113,000 to 280,000 cubic feet) of Class A low-level radioactive waste throughout the railroad operations phase. DOE would control and dispose of site-generated low-level radioactive waste in a DOE low-level waste disposal site, a site in an Agreement State, or in an NRC-licensed site, all of which would have ample capacity to accept these wastes. Therefore, impacts to low-level radioactive waste disposal facilities would be small. No low-level radioactive waste is anticipated to be generated during construction activities; therefore, no impacts to disposal facilities would occur.

Under the Shared-Use Option for either rail alignment, waste characteristics, generation rates, and disposal requirements would increase only slightly; therefore, any additional adverse impacts associated with the Shared-Use Option would be small.

6.4.1.16 Environmental Justice

The region of influence for environmental justice encompasses the regions of influence for all other resource areas because impacts in other resource areas could result in environmental justice impacts.

DOE performed the analysis of potential environmental justice impacts in accordance with Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations*, and Council on Environmental Quality guidance (DIRS 103162-CEQ 1997, all). According to the Council on Environmental Quality, a minority population exists where either (a) the minority population of the affected area exceeds 50 percent; this calculation includes federally recognized American Indian lands, because American Indians are included in the definition of minority populations; or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In addition to the 50-percent threshold, DOE used both the United States and the State of Nevada minority populations as bases for comparison.

The Council on Environmental Quality defines low-income by using the annual statistical poverty thresholds from the U.S. Census Bureau. A low-income community exists when the low-income population percentage in the area of interest is meaningfully greater than the low-income population in the general population. For purposes of the analysis of low-income communities, DOE used both the United States and the State of Nevada low-income populations as the bases for comparison. DOE assumed a 20-percent threshold above state low-income percentages in accordance with U.S. Nuclear Regulatory Commission guidance.

DOE determined whether there would be minority or low-income populations in the Caliente or Mina rail alignment regions of influence for environmental justice, and assessed whether any high and adverse impacts could fall disproportionately on minority or low-income populations. DOE also considered whether minority or low-income populations would be affected by an alternative in different ways than the general population, such as through unique exposure pathways or rates of exposure, special sensitivities, or different uses of natural resources.

For the Caliente rail alignment, the Department determined that railroad construction and operations would not result in disproportionately high and adverse impacts to minority or low-income populations. For the Mina rail alignment DOE determined that the Schurz population center and the Walker River Census County Division are the only locations where the minority populations exceed the threshold of 50 percent, and the Walker River Census County Division to be the only location where the low-income population exceeds the threshold of 20 percent over the state average of 10.5 percent established by the Nuclear Regulatory Commission and the Council on Environmental Quality. Because there are no large and adverse impacts in these areas, it cannot be concluded that low-income and minority populations in these areas would be disproportionately affected. Constructing and operating the proposed railroad along the Mina rail alignment would not result in high and adverse impacts to minority or low-income populations.

Similarly, the Department determined that under the Shared-Use Option for either rail alignment, there would be not high and adverse impacts to minority or low-income populations.

6.4.1.17 Comparison of Proposed Action and Alternatives

Council on Environmental Quality implementing regulations (40 CFR Parts 1500 through 1508) for the *National Environmental Policy Act*, as amended (NEPA) (42 U.S.C. 4321 et seq.) provide that an EIS should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public. The comparison referred to in this section is based on the information and analyses presented in the Rail Alignment EIS.

In Chapter 2, Table 2-3 highlights the differences in potential impacts under the Proposed Action for the Caliente and Mina Implementing Alternatives. This table lists the range of potential impacts under the Proposed Action for the Caliente Implementing Alternative and the Mina Implementing Alternative considering the largest and smallest potential impacts of the different alternative segments.

Potential impacts under the Shared-Use Option would be generally the same as impacts under the Proposed Action without shared use, unless noted otherwise in the tables. Potential commercial sidings and facilities that could be constructed under the Shared-Use Option would likely be constructed within the operations right-of-way to the extent practicable and, hence, the impacts of their construction are included within those impacts presented for the Proposed Action. More detailed discussion of impacts resulting from the Shared-Use Option can be found in Chapter 4 of the Rail Alignment EIS.

Table 2-3 illustrates that the Mina Implementing Alternative would be environmentally preferable when compared to the Caliente Implementing Alternative. In general, the Mina Implementing Alternative would have fewer private-land conflicts, less surface disturbance, smaller impacts to wetlands, and smaller impacts to air quality that than the Caliente Implementing Alternative. However, the Mina Implementing Alternative is the DOE nonpreferred alternative due to the objection of the Walker River Paiute Tribe to the transportation of spent nuclear fuel and high-level radioactive waste through the Walker River Paiute Reservation.

6.4.2 TRANSPORTATION IMPACTS FROM REPOSITORY ACTIVITIES

DOE would transport construction materials, repository components, and consumables to the repository on trucks on Nevada highways, and on trains along the Caliente or Mina rail corridor. Shipments of construction materials would include 190,000 metric tons (210,000 tons) of cement; 280,000 metric tons (310,000 tons) of steel; and 670 metric tons (740 tons) of copper. Shipments of repository components would include 11,200 empty waste packages, 11,200 *emplacement* pallets, 11,500 drip shields, 2,500 *aging overpacks*, and about 1,000 TAD canisters. About 6,500 additional empty TAD canisters would be shipped directly to the generator sites. The impacts of shipping these 6,500 empty TAD canisters to the generator sites were included in Section 6.2.1. Most of the consumables would be fuel oil; about 8,100 railroad tank cars of fuel oil would be shipped to the repository during the operations period. In total, there would be about 37,000 railcar shipments of construction materials, repository components, and consumables to the repository. These shipments would account for 57 to 61 million railcar kilometers (36 to 38 million railcar miles) of round-trip travel in Nevada. Shipments of repository components would account for about 86 to 91 million railcar kilometers (54 to 56 million railcar miles) of round-trip travel on the national level. DOE would ship waste materials from repository activities off the site. This waste would include nonhazardous *solid waste*, and hazardous, mixed, and low-level radioactive wastes. Workers would commute to the repository; DOE would provide bus service from Clark and Nye counties for these workers. In addition, the analysis assumed that 80 percent of the workers would live in Clark County and 20 percent would live in Nye County. During the construction, operations, monitoring, and closure periods, these workers would account for about 1,900 million vehicle kilometers (1,200 million vehicle miles) of round trip travel from Nye and Clark counties in Nevada.

Table 6-16 lists the impacts from the transportation of these materials and from worker commutes. DOE estimated that there would be about 13 vehicle emission fatalities and 44 to 46 traffic fatalities.

Table 6-16. Impacts from transportation of material and people.

Category	Vehicle emission fatalities	Traffic fatalities
Caliente Corridor		
Construction materials, repository components, consumables, and waste materials	0.89	7.9
Commuting workers	12	36
Total	13	44
Mina Corridor		
Construction materials, repository components, consumables, and waste materials	0.86	11
Commuting workers	12	35
Total	13	46

Notes: Includes impacts from the construction and operation of the Caliente and Mina rail corridors for the Shared-Use Option. Values are rounded to two significant figures; therefore, totals might differ from sums.

Evaluation of these transportation activities resulted in impacts that were greater than the impacts presented in the Yucca Mountain FEIS. The primary reasons for the increase were extrapolating impacts to 2067 instead of 2035, increasing the number of construction workers required to build the Nevada rail line, increasing the repository operations period from 24 years to up to 50 years, increasing rail shipments to account for the Shared-Use Option for the Caliente and Mina rail corridors, and including workers who work in Las Vegas in the estimates of vehicle emission and traffic fatalities.

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7

Environmental Impacts of the No-Action Alternative

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7. ENVIRONMENTAL IMPACTS OF THE NO-ACTION ALTERNATIVE

This chapter describes potential *impacts* for the *No-Action Alternative* that the U.S. Department of Energy (DOE or the Department) described in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS) and Chapter 2 of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). The purpose of the No-Action Alternative is to provide a basis for comparison with the impacts of the *Proposed Action*. Under the No-Action Alternative, DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate significant adverse environmental impacts. Commercial utilities and DOE would continue to store and manage *spent nuclear fuel* and *high-level radioactive waste* at 76 sites in the United States in a manner that protected public health and safety and the *environment*. This Repository SEIS updates the health and safety impacts of the No-Action Alternative in the Yucca Mountain FEIS to reflect updated *radiation* dosimetry and *latent cancer fatality* conversion factors. This Repository SEIS incorporates the more detailed discussion of the analysis and environmental impacts associated with the No-Action Alternative to the Proposed Action by reference to Chapter 7 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 7-1 to 7-59).

7.1 Changes to the Analysis of the No-Action Alternative

DOE has performed an assessment of the analytical areas it evaluated for the No-Action Alternative in the Yucca Mountain FEIS to determine the areas that warranted updates. Throughout this Repository SEIS, DOE has used two updated analytical parameters in the determination of radiological health impacts: (1) radiation dosimetry and (2) latent cancer fatality conversion factors. To provide a basis of comparison with the Proposed Action, DOE has updated the radiological health impacts from the No-Action Alternative in the Yucca Mountain FEIS to reflect the changes in these parameters. The following sections provide the background on these changes.

7.1.1 RADIATION DOSIMETRY

Radioactive material released to the environment could affect persons who come in contact with it. Mechanisms for transporting radioactive material include air, water, soil, and food. The various ways an individual or population can come into contact with radioactive material are known as *pathways*. An individual can come into contact with radioactive material directly through the external and inhalation pathways or indirectly through the ingestion pathway. For this Repository SEIS, DOE evaluated five pathways for *exposure* to radioactive material:

- Inhalation,
- Ingestion,
- Inhalation of previously deposited material resuspended from the ground (resuspension),
- External exposure to material deposited on the ground (groundshine), and
- External exposure to material in the air (*immersion* or *cloudshine*).

The factors that DOE used to convert estimates of *radionuclide* intake (by inhalation or ingestion) or exposure (by groundshine or immersion) to a radiation *dose* are called dose coefficients. For this Repository SEIS, DOE used the International Commission on Radiological Protection inhalation and ingestion dose coefficients from *The ICRP Database of Dose Coefficients: Workers and Members of the Public* (DIRS 172935-ICRP 2001, all) and the groundshine and immersion dose coefficients from *Federal Guidance Report 13, CD Supplement, Cancer Risk Coefficients for Environmental Exposure to Radionuclides, EPA* (DIRS 175544-EPA 2002, all) to estimate radiation doses. The Department based its use of these dose coefficients on, and incorporated them from, the recommendations of the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, all; DIRS 152446-ICRP 1996, all; respectively). Some dose coefficients have increased and some have decreased. Therefore, changes in radiation doses as a result of changes in dose coefficients are not uniform.

7.1.2 LATENT CANCER FATALITY CONVERSION FACTORS

Current DOE guidance recommends that the Department base estimates of latent cancer fatalities on received radiation dose and on dose-to-health effect conversion factors recommended by the Interagency Steering Committee on Radiation Standards. For this Repository SEIS, DOE used the updated guidance for workers and members of the public. The latent cancer fatality conversion factor is 0.0006 fatality per *person-rem* (DIRS 174559-Lawrence 2002, p. 2).

7.2 Summary of No-Action Alternative Impacts

Under the No-Action Alternative, *decommissioning* and reclamation would begin as soon as practicable and could take several years to complete. Decommissioning and reclamation would include removal or shutdown of existing surface and *subsurface facilities* and restoration of disturbed lands. Short-term impacts from site reclamation at Yucca Mountain would be small. Table 7-1 summarizes the local short-term impacts by resource area.

DOE recognizes that the future course Congress, DOE, and the commercial utilities would take if the U.S. Nuclear Regulatory Commission (NRC) did not license the *Yucca Mountain Repository* is uncertain. DOE further recognizes that it and the nuclear utilities could pursue a number of possibilities that include the continued storage of spent nuclear fuel and high-level radioactive waste at each generator site in expanded onsite storage facilities; storage of these materials at one or more centralized locations; study and selection of another location for a deep *geologic repository* (Chapter 1 of the Yucca Mountain FEIS identified the alternative sites DOE previously selected for technical study as potential *geologic* repository locations); development of new technologies; or reconsideration of *alternatives* to geologic *disposal*. Other documents have analyzed the environmental considerations of these possibilities in other contexts to varying degrees. Table 7-1 of the Yucca Mountain FEIS described studies related to centralized or regionalized interim storage that included alternatives in DOE *National Environmental Policy Act* documents, and summarized the relevant considerations. As mentioned below, some of these documents have been updated.

The proposed Private Fuel Storage Facility on the reservation of the Skull Valley Band of Goshute Indians in Tooele County, Utah, is an example of the difficulty in predicting sustainable alternatives to storage and disposal of spent nuclear fuel. The NRC licensed this facility on February 21, 2006 (DIRS 181683-Ruland 2006, all). However, the construction of the facility has not begun due to a failure to lease the site or obtain the necessary right-of-way access across federally managed land. Both the Bureau

Table 7-1. No-Action Alternative short-term impacts in the Yucca Mountain vicinity.

Resource area	Environmental impacts
Land use and ownership	DOE would require no new land to support decommissioning and reclamation; it would restore disturbed land to its approximate preconstruction condition.
Air quality	Dismantling and removal of existing structures, recontouring, and revegetation would generate fugitive dust that would be below the regulatory limits.
Hydrology (surface water)	Recontouring of terrain to restore the natural drainage and manage potential surface-water contaminant sources would minimize surface-water impacts.
Hydrology (groundwater)	DOE would use a small amount of groundwater during decommissioning and reclamation.
Biological resources and soils	Reclamation would result in the restoration of 1.4 square kilometers (350 acres) of habitat. Site reclamation would include soil stabilization and revegetation of disturbed areas. Some animal species could take advantage of abandoned tunnels for shelter. Decommissioning and reclamation could produce adverse impacts to the threatened desert tortoise.
Cultural resources	Leaving roads in place after decommissioning could have an adverse impact on cultural resources by increasing public access to the site. Preserving the integrity of important archeological sites and resources important to American Indians could be difficult.
Socioeconomics	The No-Action Alternative would result in the loss of approximately 4,700 jobs (1,800-person workforce for decommissioning and reclamation, 1,400-person engineering and technical personnel in locations other than the repository site, and 1,500 indirect jobs) in the socioeconomic region of influence. Nye County collects most of the federal monies associated with the repository project. The No-Action Alternative would result in the loss of payments in lieu of taxes to Nye County.
Occupational and public health and safety	During decommissioning and reclamation, workers and members of the public would be exposed to nonradioactive and radioactive materials. Doses to worker population could be as high as 150 person-rem as a result of radioactive radon decay, which would result in an estimated 0.09 latent cancer fatality. Annual radiation dose to the offsite population would be less than 2 person-rem, which would result in an estimated 0.001 latent cancer fatality.
Accidents	Accident impacts would be limited to those from traffic and typical industrial hazards encountered during construction or excavation activities. These were estimated at 94 total recordable cases and 45 lost workday cases.
Noise	Noise levels would be no greater than the current baseline noise environment at the Yucca Mountain site.
Aesthetics	Site decommissioning and reclamation would improve the scenic value of the site, which DOE would return to a state as close as possible to its predisturbance state.
Utilities, energy, materials, and site services	Decommissioning would consume electricity, diesel fuel, and gasoline. The No-Action Alternative would not adversely affect the utility, energy, or material resources of the region.
Waste management	Decommissioning would generate some waste that would require disposal in existing Nevada Test Site landfills. DOE would minimize waste by salvaging most equipment and many materials.

Table 7-1. No-Action Alternative short-term impacts in the Yucca Mountain vicinity (continued).

Resource area	Environmental impacts
Traffic and transportation	Less than 0.15 traffic fatality would be likely during decommissioning and reclamation.
Environmental justice	Disproportionately high and adverse impacts to minority or low-income populations would be unlikely because there is no reason to believe they would be any more likely to be affected by job loss.

Note: Conversion factors are on the inside back cover of this Repository SEIS.
DOE = U.S. Department of Energy.

of Indian Affairs and the Bureau of Land Management have disapproved construction and operation of the facility (DIRS 181684-Cason 2006, p. 29; DIRS 181685-Calvert 2006, p. 1).

In light of these types of uncertainties and DOE's conclusion that no action would not result in predictable actions by others, the Yucca Mountain FEIS considered the range of possibilities by focusing the analysis of the No-Action Alternative on the potential impacts of two scenarios.

In No-Action Scenario 1, DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-ground dry-storage facilities at DOE sites around the country. Commercial utilities would continue to manage their spent nuclear fuel at current locations. The commercial and DOE sites would remain under *institutional control*; that is, they would be maintained to ensure the protection of workers and the public in accordance with current federal regulations. The storage facilities would be replaced every 100 years. They would undergo one major repair during the first 100 years because this scenario assumes that the design of the first storage facilities at a site would include a facility life of less than 100 years. The facility replacement period of 100 years represents the assumed useful lifetime of the structures. Replacement facilities would be on land adjacent to the existing facilities.

In No-Action Scenario 2, spent nuclear fuel and high-level radioactive waste would remain in *dry storage* at commercial and DOE sites and would be under institutional control for approximately 100 years (the same as Scenario 1). Beyond that time, the scenario assumed no institutional control. Therefore, after about 100 years and up to 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at commercial and DOE sites would begin to deteriorate and would eventually release radioactive materials to the environment.

Table 7-2 summarizes No-Action Alternative impacts at commercial and DOE sites for both scenarios from 100 to 10,000 years. From a *qualitative* standpoint, the long-term health impacts of the No-Action Alternative scenarios can be estimated for a longer period (that is, 1 million years). Because the scope of the Scenario 1 impacts (with institutional controls) is related to rebuilding the storage installations every 100 years, the estimate of the Scenario 1 impacts over 1 million years would be a time-step function of the 10,000-year value. In other words, the annual impacts would be the same or less (due to radioactive decay), but the integrated impacts over the million-year period would be approximately 100 times those of the 10,000-year impacts in Table 7-2.

The scope of health impacts over 1 million years for Scenario 2 is more speculative. The No-Action Alternative evaluation of the 10,000-year period in the Yucca Mountain FEIS showed that the original storage facility and containment vessels of the spent nuclear fuel and high-level radioactive waste would

Table 7-2. No-Action Alternative impacts at commercial and DOE sites.

Resource area	Short-term impacts (100 years)	Long-term impacts (100 to 10,000 years)	
		Scenario 1	Scenario 2
Land use and ownership	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential contamination of 0.04 to 0.4 km^2 surrounding each commercial and DOE site.
Air quality	Small; releases and exposures well below regulatory limits.	Small; releases and exposures well below regulatory limits.	Small; degraded facilities would preclude large atmospheric releases.
Hydrology			
Groundwater	Small, usage would be small in comparison with other site use.	Small; usage would be small in comparison with other site use.	Large; potential for radiological contamination of groundwater around the commercial and DOE sites.
Surface water	Small; minor changes to runoff and infiltration rates.	Small; minor changes to runoff and infiltration rates.	Large; potential for radiological releases and contamination of drainage basins downstream of commercial and DOE sites (concentrations potentially exceeding current regulatory limits).
Biological resources and soils	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential adverse impacts at each of the sites from subsurface contamination of 0.04 to 0.4 km^2.
Cultural resources	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; no construction or operation activities; no impacts.
Socioeconomics	Small; population and employment changes would be small compared with totals in the regions.	Small; population and employment changes would be small compared with totals in the regions.	No workers; therefore, no impacts.
Occupational and public health and safety			
Public – Radiological MEI (probability of an LCF)	0.0000052[a]	[a]	
Public – Population (LCFs)	0.49[a]	3.1[a]	[c]
Public – Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Moderate to large; substantial increases in releases of hazardous substances and exposures to the public.
Workers – Radiological (LCFs)	24[a]	[a]	No workers; therefore, no impacts.
Workers – Nonradiological fatalities (includes commuting traffic fatalities)	9	1,080	No workers; therefore, no impacts.

0.0000016

(b)

1,000

Table 7-2. No-Action Alternative impacts at commercial and DOE sites (continued).

Resource area	Short-term impacts (100 years)	Long-term impacts (100 to 10,000 years) Scenario 1	Scenario 2
Accidents			
Public – Radiological MEI (probability of an LCF)	None.	None.	Not applicable.
Public – Population (LCFs)[d]	None.	None.	4 to 16[e]
Workers	Large; for some unlikely accident scenarios workers probably would be severely injured or killed; however, DOE or NRC would manage facilities safely during continued storage operations.	Large; for some unlikely accident scenarios workers would probably be severely injured or killed.	No workers; therefore, no impacts.
Noise	Small; transient and not excessive, less than 85 dBA.	Small; transient and not excessive, less than 85 dBA.	No activities, therefore, no noise.
Aesthetics	Small; storage would continue at existing sites; expansion as needed.	Small; storage would continue at existing sites; expansion as needed.	Small; aesthetic value would decrease as facilities degraded.
Utilities, energy, materials, and site services	Small; materials and energy use would be small compared with total site use.	Small; materials and energy use would be small compared with total site use.	No use of materials or energy; therefore, no impacts.
Waste Management	Small; waste generated and materials used would be small compared with total site generation and use.	Small; waste generated and materials used would be small compared with total site generation and use.	No generation of waste or use of hazardous materials; therefore, no impacts.
Environmental justice	Small; no disproportionately high and adverse impacts to minority or low-income populations.	Small; no disproportionately high and adverse impacts to minority or low-income populations.	Large; potential for disproportionately high and adverse impacts to minority or low-income populations.

Source: DIRS 155970-DOE 2002, pp. 2-79 to 2-82.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Updated using a conversion factor of 0.0006 LCF per person-rem; no change to external dose coefficients.

b. With no effective institutional controls, the MEI could receive a fatal dose of radiation within a few weeks to months. Death could be caused by acute direct radiation exposure.

c. Updated using a conversion factor of 0.0006 LCF per person-rem and ingestion dose coefficients that overall are about 25 percent of the coefficients used in the Yucca Mountain FEIS.

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

e. Updated using a conversion factor of 0.0006 LCF per person-rem and inhalation dose coefficients that are approximately the same as coefficients used in the Yucca Mountain FEIS.

dBA = A-weighted decibel.
DOE = U.S. Department of Energy.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.

be compromised and dissolution of these materials would cause radionuclides to enter the accessible environment. The Scenario 2 health impacts in Table 7-2 indicate the catastrophic impacts that this scenario could cause. Beyond 10,000 years, the unchecked deterioration and dissolution of the materials would continue and increase impacts even further. The increasing uncertainty (for example, actual locations of radiological materials, climate changes, and degree of institutional control) over this extended period, however, does not provide a meaningful basis for *quantitative* impact analyses because of the limitless number of scenarios that could occur.

7.3 Cumulative Impacts for the No-Action Alternative

DOE analyzed cumulative impacts of the continued storage of all spent nuclear fuel and high-level radioactive waste (Inventory Module 1, as discussed in detail in Chapter 8 of this Repository SEIS) at the commercial and DOE facilities for the No-Action Alternative in the Yucca Mountain FEIS. This section summarizes and incorporates by reference Section 7.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 7-43 to 7-54).

The Yucca Mountain FEIS demonstrated that the impacts of continued storage of spent nuclear fuel and high-level radioactive waste would be directly proportional to the increased amount of commercial spent nuclear fuel in Inventory Module 1. In the FEIS, the amount of commercial spent nuclear fuel in Inventory Module 1 was approximately 70 percent higher than that in the Proposed Action. The resultant impacts of continued storage of these materials were approximately 1.7 times the impacts from storage of the *Proposed Action inventory*. By applying this linear relationship to the updated Inventory Module 1, the impacts of continued storage of the 130,000 *metric tons of heavy metal* of commercial spent nuclear fuel would be approximately twice that of the Proposed Action (Chapter 8 of this Repository SEIS contains more details). Table 7-3 lists estimates of the health impacts of the continued storage of Inventory Module 1 based on this linear relationship. The long-term impacts in Table 7-3 are estimates of the impacts that could occur within 10,000 years. As discussed in Section 7.2, the impacts of continued storage for 1 million years would be higher.

Table 7-3. No-Action Alternative health impacts from continued storage of Inventory Module 1 at commercial and DOE sites.

Resource area	Short-term impacts (100 years)	Long-term impacts (100 to 10,000 years) Scenario 1	Scenario 2
Occupational and public health and safety			
Public – Radiological MEI (probability of an LCF)	0.00001	0.000003	(a)
Public – Population (LCFs)[b]	1	6	2,000
Public – Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Moderate to large; substantial increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public.
Workers – Radiological (LCFs)	48	30	No workers; therefore, no impacts.
Workers – Nonradiological fatalities (includes commuting traffic fatalities)	18	2,200	No workers; therefore, no impacts.

a. With no effective institutional controls, the MEI could receive a fatal dose of radiation within a few weeks to months. Cause of death would be acute direct radiation exposure.
b. Downstream exposed population of approximately 3.9 billion over 10,000 years.
DOE = U.S. Department of Energy.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.

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181684	Cason 2006	Cason, J.E. 2006. *Record of Decision for the Construction and Operation of an Independent Spent Fuel Storage Installation (ISFSI) on the Reservation of the Skull Valley Band of Goshute Indians (Band) in Tooele County, Utah.* Washington, D.C.: U.S. Department of Interior, Bureau of Indian Affairs. ACC: MOL.20070712.0053.
155970	DOE 2002	DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; MOL.20020524.0315; MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319; MOL.20020524.0320.

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Cumulative Impacts

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8. CUMULATIVE IMPACTS

This chapter describes potential cumulative impacts for the Proposed Action of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). An evaluation of cumulative impacts is necessary to understand the environmental implications of implementing the Proposed Action and is essential to the development of appropriate mitigation measures and the monitoring of their effectiveness.

The U.S. Department of Energy (DOE or the Department) followed the Council on Environmental Quality regulations handbook *Considering Cumulative Effects Under the National Environmental Policy Act* (DIRS 103162-CEQ 1997, all) that implements the procedural provisions of the *National Environmental Policy Act of 1969*, as amended (42 U.S.C. 4321 et seq.). The Council on Environmental Quality regulations define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). The term "reasonably foreseeable" refers to future actions for which there is a reasonable expectation that the action could occur, such as a proposed action under analysis, a project that has already started, or a future action that has obligated funding. Thus, DOE identified actions that could have effects that coincided in time and space with the effects from the proposed repository and associated transportation activities. The Department based its identification of the relevant actions on reviews of resource, policy, development, and land use plans from agencies at all levels of government and from private organizations; other environmental impact statements; and environmental assessments. In addition to the assessment of potential cumulative impacts and consistent with Council on Environmental Quality regulations [40 CFR 1502.16(c) and 1506.2], this cumulative impacts analysis considered potential conflicts with plans issued by various government entities to the extent practicable and to the extent they provided relevant information. Past, present, and reasonably foreseeable future actions could contribute incrementally to the overall cumulative impacts.

This chapter summarizes, incorporates by reference, and updates the information in Chapter 8 of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS). DOE has organized this chapter as follows:

- Section 8.1 presents past, present, and reasonably foreseeable future federal, non-federal, and private actions. This includes a detailed analysis of nuclear materials in need of permanent disposal in addition to those evaluated for the Proposed Action. It describes and evaluates these waste quantities, which it refers to as Inventory Modules 1 and 2.

- Section 8.2 presents cumulative preclosure impacts in the proposed Yucca Mountain Repository region that could occur during the construction, operation and monitoring, and closure of the repository. DOE organized this section by resource area, which corresponds to Chapter 4 of this Repository SEIS. The analysis included only the resource areas with potential cumulative impacts.

- Section 8.3 discusses the results from the postclosure cumulative impact analysis DOE conducted for Inventory Modules 1 and 2, the Nevada Test Site, and the Beatty low-level radioactive waste disposal and hazardous waste treatment storage and disposal facilities.
- Section 8.4 presents cumulative transportation impacts for national and Nevada transportation.
- Section 8.5 describes potential cumulative impacts from the manufacturing of the repository components that would be necessary to emplace Inventory Module 1 or 2.
- Section 8.6 presents a summary table of cumulative impacts. In addition, this section presents a perspective on the cumulative impacts of these actions from the viewpoint of Nye County, Nevada, which is a cooperating agency on this Repository SEIS.

8.1 Past, Present, and Reasonably Foreseeable Future Actions

This section identifies past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action for this Repository SEIS.

8.1.1 PAST AND PRESENT ACTIONS

The description of existing environmental conditions in Chapter 3 includes the impacts of most past and present actions on the environment that the Proposed Action would affect. This includes site characterization activities at Yucca Mountain. Therefore, the Chapter 4, 5, and 6 analyses of potential environmental impacts of the Proposed Action generally encompass the impacts of past and present actions because the baseline for these analyses is the affected environment described in Chapter 3. Table 8-1 lists two past actions that the Chapter 3 environmental baseline does not address but that DOE identified for inclusion in the cumulative impact analysis. The table also lists information on the potential areas with cumulative impact from these two actions.

Table 8-1. Past and present actions that could result in potential cumulative impacts with the Proposed Action.

	Potential cumulative impact areas			
Past and present action and description	Preclosure	Postclosure	Transportation	Manufacturing
Nevada Test Site				
Nuclear weapons testing, waste management	Air quality and public health and safety	Air quality, groundwater, and public health and safety	Occupational and public radiological health and safety	None
Beatty Waste Disposal Area				
Low-level radioactive and hazardous waste disposal	None	Groundwater and public health and safety	Occupational and public radiological health and safety	None

In addition to the specific actions in Table 8-1, the cumulative impacts for national transportation consider the occupational and public radiological health impacts of other past, present, and reasonably foreseeable future shipments of radioactive material.

8.1.2 REASONABLY FORESEEABLE FUTURE ACTIONS

This section describes the reasonably foreseeable future actions that the cumulative impacts analysis considered. These actions could affect the repository region of influence. Section 8.4 discusses potential effects to national and Nevada transportation. Table 8-2 summarizes the reasonably foreseeable future actions that could result in potential cumulative impacts with the Proposed Action.

Table 8-2. Reasonably foreseeable future actions that could result in potential cumulative impacts with the Proposed Action.

Name/description	Change from the Yucca Mountain FEIS to the Repository SEIS
Inventory Module 1 Disposal of all SNF and HLW	Increase in projected inventory.
Inventory Module 2 Disposal of Inventory Module 1, as well as GTCC and SPAR wastes	Increase in Module 1 projected inventory, which would increase Module 2 projected inventory.
Nevada Test and Training Range	Additional actions.
Nevada Test Site	Additional actions.
DOE	
Programmatic Environmental Impact Statement GNEP (DOE/EIS-0396).	New action.
EIS for Disposal of GTCC Low-Level Radioactive Waste (DOE/EIS-0375)	New action.
National Nuclear Security Administration Complex Transformation Supplemental PEIS – environmental impacts from the continued transformation of the U.S. nuclear weapons complex	New action.
DOE and BLM have issued a notice of intent for a Programmatic EIS on federal land in 11 western states, including Nevada, for oil, gas, and hydrogen pipelines and electricity transmission and distribution facilities and corridors (70 FR 56647, September 28, 2005)	New action.
Nye County	
Yucca Mountain Project Gateway Area Concept Plan for the Yucca Mountain Project entrance (DIRS 182345-Giampaoli 2007, all)	New action.
Desert Space and Science Museum Construction of a science museum (DIRS 182345-Giampaoli 2007, all)	Nye County has decreased acreage for the project since completion of the Yucca Mountain FEIS.
Private Fuel Storage at Skull Valley, Utah Temporary storage of SNF at the Goshute Reservation in Utah 71 FR 10068, February 28, 2006. DIRS 157761-NRC 2001, all. DIRS 181684- Carson 2006. DIRS 181685- Calvert 2006.	Federal Register Notice on February 28, 2006-NRC licensed facility. Bureau of Indian Affairs and BLM delivered a no-action decision on the plan on September 7, 2006.

AFB = Air Force Base.
BLM = U.S. Bureau of Land Management.
DOE = U.S. Department of Energy.
EA = Environmental assessment.
EIS = Environmental impact statement.
GNEP = Global Nuclear Energy Partnership.
GTCC = Greater-Than-Class-C.
HLW = High-level radioactive waste.
NRC = U.S. Nuclear Regulatory Commission.
NTS = Nevada Test Site.
SNF = Spent nuclear fuel.
SPAR = Special Performance Assessment Required.

8.1.2.1 Inventory Modules 1 and 2

Under the Proposed Action, DOE would emplace as much as 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste in the proposed repository. Of the 70,000 MTHM, approximately 63,000 MTHM would be commercial spent nuclear fuel and commercial high-level waste. The remaining 7,000 MTHM would consist of DOE materials (spent nuclear fuel and high-level radioactive waste).

As in the Yucca Mountain FEIS, DOE analyzed the emplacement of Inventory Modules 1 and 2 as a reasonably foreseeable action. Under Module 1, DOE would emplace all of the projected spent nuclear fuel and high-level radioactive waste. Under Module 2, DOE would emplace all of Inventory Module 1 plus other radioactive materials that could require disposal in a monitored geologic repository (commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste). This Repository SEIS updates, as necessary, the estimated inventories of these modules. As stated in the Yucca Mountain FEIS, DOE acknowledges the need for legislative action by Congress before these actions could occur.

Under the updated inventory for Module 1, DOE would emplace all projected commercial spent nuclear fuel (about 130,000 MTHM) (DIRS 182343-BSC 2006, all), all DOE spent nuclear fuel (about 2,500 MTHM) (DIRS 155970-DOE 2002, all) and all high-level radioactive waste (approximately 36,000 canisters) (DIRS 182361-Koutsandreas 2007, all). As a point of reference, the amount of commercial spent nuclear fuel that DOE discussed in the Yucca Mountain FEIS was about 105,000 MTHM.

The only changes to Inventory Module 2 are the changes associated with Inventory Module 1. There are no changes to the Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste for Inventory Module 2 from those in the Yucca Mountain FEIS. The estimated quantities of these other wastes are about 2,000 cubic meters (71,000 cubic feet) of Greater-Than-Class-C waste and about 4,000 cubic meters (140,000 cubic feet) of DOE Special-Performance-Assessment-Required waste (also referred to as Greater-Than-Class-C-like waste; see Section 8.1.2.4.1). Appendix A of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. A-1 to A-71)) contains further details on these inventories. DOE has started preparation of an environmental impact statement for the disposal of Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste. Updated inventories might be available in the future; however, preliminary indications are that the Yucca Mountain FEIS inventories of these materials and the methods used in this Repository SEIS would bound the impacts of disposal of these inventories.

This Repository SEIS examines the potential impacts of disposal of Inventory Module 1 by evaluating the following factors:

- The Repository SEIS Module 1 commercial spent nuclear fuel inventory (130,000 MTHM) is approximately twice that of the Repository SEIS Proposed Action amount (63,000 MTHM).

- The Yucca Mountain FEIS established an analytical relationship between the impacts in each environmental resource area for the Proposed Action and those of Inventory Module 1. This relationship, which was based on detailed analyses, did not always result in a linear increase in relation to the higher amount of materials.

- The Yucca Mountain FEIS Module 1 commercial spent nuclear fuel inventory (105,000 MTHM) is about 67 percent higher than that of the FEIS Proposed Action amount (63,000 MTHM).

Chapters 4, 5, and 6 of this Repository SEIS present the environmental impacts for the Proposed Action.

Beyond the changes to Inventory Module 1, Inventory Module 2 for this Repository SEIS has not changed, so the SEIS has incorporated the incremental increase in cumulative impacts from Module 2 by reference to the analysis in the Yucca Mountain FEIS.

8.1.2.2 Nevada Test and Training Range

The U.S. Air Force operates the Nevada Test and Training Range (formerly known as the Nellis Air Force Range) in south-central Nevada (Figure 8-1), a national test and training facility for military equipment and personnel that consists of approximately 12,000 square kilometers (3 million acres). In *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all) the Air Force addressed potential environmental impacts of extending the land withdrawal to continue use of the Nevada Test and Training Range lands for military use. In 2005, the Air Force designated the Indian Springs Air Force Auxiliary Airfield as Creech Air Force Base and expanded its mission and infrastructure to play a major role in the war on terrorism. The base is home to two key military operations: the MQ-1 unmanned aerial vehicle and the Unmanned Aerial Vehicle Battle laboratory. The 1,600-square-kilometer (390,000-acre) Bureau of Land Management-administered National Wild Horse Management Area is within the boundary of the Nevada Test and Training Range. More than 3,200 square kilometers (800,000 acres) of the Test and Training Range comprise the Desert National Wildlife Range. The Air Force and the U.S. Fish and Wildlife Service jointly manage this area. In 2004, the Bureau of Land Management prepared a resource management plan for about 8,900 square kilometers (2.2 million acres) of withdrawn public lands on the Test and Training Range (DIRS 178102-BLM 2004, all). The plan guides the management of the affected Range natural resources 20 years into the future (2024). The decisions, directions, allocations, and guidelines in the plan are based on the primary use of the withdrawn area for military training and testing purposes. Environmental assessments are periodically completed for new or changing activities at the Range. Table 8-3 is a summary of Nevada Test and Training Range environmental assessments identified since the completion of the Yucca Mountain FEIS.

8.1.2.3 Nevada Test Site

The Nevada Test Site was established in 1951 as the nation's proving ground for developing and testing nuclear weapons (Figure 8-1). The site is on land administratively held by the Bureau of Land Management, but the Test Site land was withdrawn for use by the Atomic Energy Commission and its successors (including DOE). At present, the National Nuclear Security Administration manages the site, which consists of about 3,200 square kilometers (800,000 acres) of land.

A number of defense-related material and management activities, waste management, environmental restoration, and non-defense research and development are conducted at the site. DOE activities at the Nevada Test Site include stockpile stewardship and management (helping ensure the U.S. nuclear weapon stockpile is safe, secure, and reliable), materials disposition (removal of nuclear materials in a safe and timely manner), and nuclear emergency response. Between 1951 and 1992, the Federal Government conducted just over 900 nuclear tests at the site. The *Final Environmental Impact Statement for the*

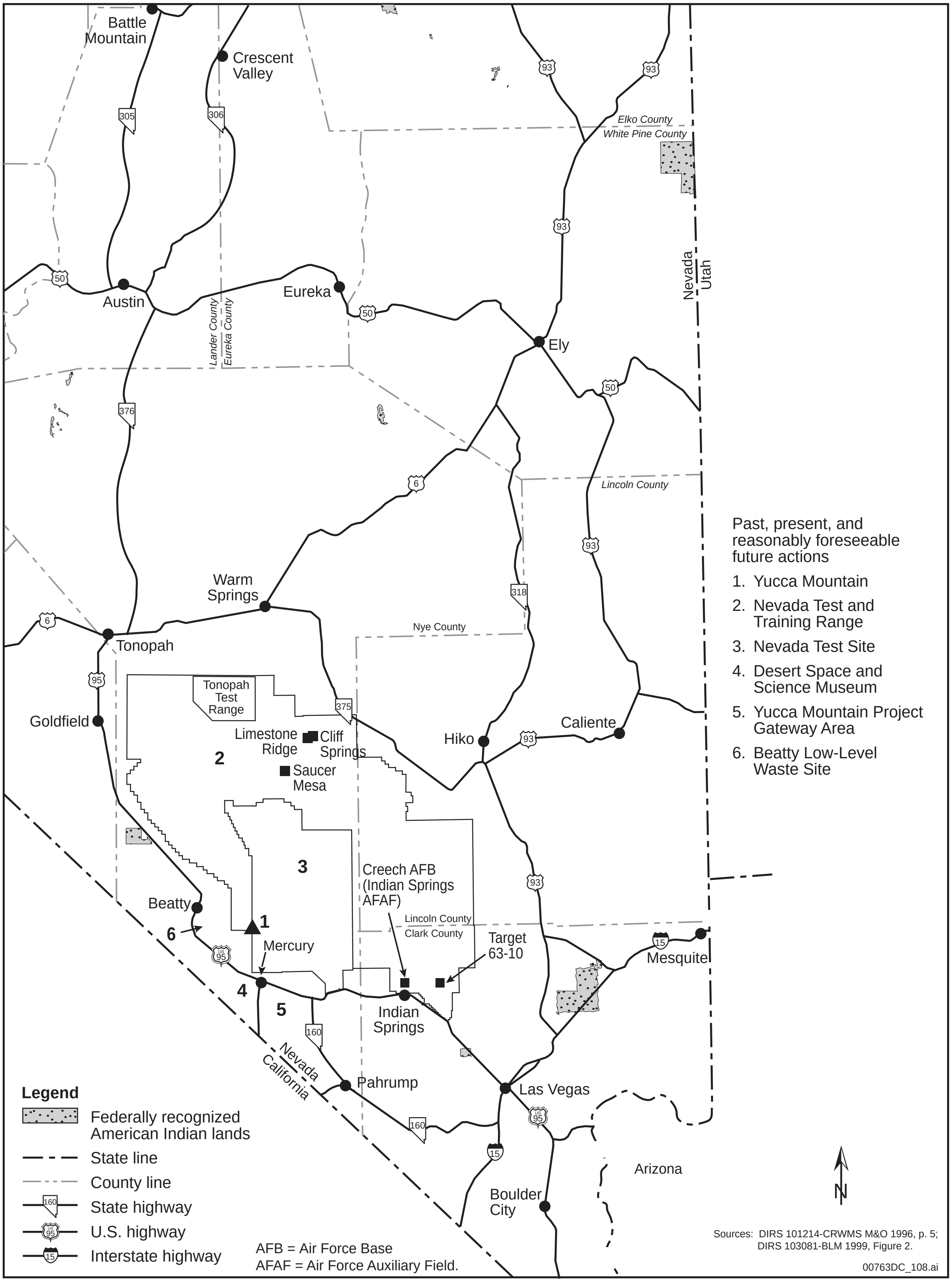

Figure 8-1. Locations of past, present, and reasonably foreseeable future actions.

Table 8-3. Environmental assessments identified since completion of the Yucca Mountain FEIS for the Nevada Test and Training Range.

Title	Description
Final Environmental Assessment for Increased Depleted Uranium Use on Target 63-10, Nevada Test and Training Range (DIRS 181607-USAF 2006, all)	The proposed action was to increase the use of depleted uranium ammunition at the Nevada Test and Training Range to meet ongoing test and training requirements for A-10 aircraft. The Air Force was to increase the number of depleted uranium rounds authorized to be fired on Target 63-10 from 7,900 to 19,000 annually. The environmental assessment evaluated five resource areas—air quality, soils and water resources, health and safety, hazardous and radioactive materials and waste, and biological resources—in detail to identify potential environmental impacts. The Air Force issued a Finding of No Significant Impact.
Final Environmental Assessment for Predator Force Structure Changes at Indian Springs Air Force Auxiliary Field, Nevada (DIRS 172314-USAF 2003, all)	The proposed action included changes to personnel assignments, upgrades to existing facilities, construction of new facilities, and extension of a runway by 120 meters (400 feet). The Air Force completed facilities for the Predator unmanned aerial vehicles in 2006. The Air Force issued a Finding of No Significant Impact.
Expeditionary Readiness Training Course Expansion, Final Environmental Assessment, Creech AFB (DIRS 182838-USAF 2006, all)	Environmental assessment to increase the number of Security Forces personnel trained at the Regional Training Center at Sliver Flag Alpha and Creech AFB, Nevada, from an existing 2,520 to 6,000 students per year. The Air Force issued a Finding of No Significant Impact.
Wing Infrastructure Development Outlook, Final Environmental Assessment, Nellis AFB (DIRS 182839-USAF 2006, all)	The proposed action consists of 630 Wing Infrastructure and Development Outlook projects in 11 categories as classified under 32 CFR Part 989, *Air Force EIAP*. A total of 18 new construction and demolition projects are proposed for Creech Air Force Base. On the Nevada Test and Training Range, the proposed action would implement four new construction projects at four locations. At Tonopah Test Range, three new construction projects are planned along with the demolition of 10 buildings. The Air Force issued a Finding of No Significant Impact.
Draft Range 74 Target Complexes Environmental Assessment Nevada Test and Training Range, Nevada (DIRS 182840-USAF 2007, all)	The proposed action is to construct and operate three target complexes in mountainous terrain in Range 74 of the Nevada Test and Training Range at Saucer Mesa, Limestone Ridge, and Cliff Springs. The Saucer Mesa target array would employ both large-scale live and inert munitions; the Limestone Ridge sites would employ large-scale inert munitions; both target sites would employ small-scale live munitions. The Cliff Springs target complex would be laser and simulated attack targets and no munitions would be used. The Air Force issued a Finding of No Significant Impact.
A Final Base Realignment and Closure Environmental Assessment for Realignment of Nellis Air Force Base (DIRS 181492-USAF 2007, all)	The proposed action would affect the Nevada Test and Training Range by adding 1,400 F-16 sorties flown from Nellis Air Force Base. Although they would not cause total annual sortie operations to exceed the current maximum of 300,000 at the Nevada Test and Training Range. The environmental assessment evaluated noise, air quality, socioeconomics and infrastructure, water and soil resources, biological resources, cultural resources, and hazardous materials and waste. The Air Force issued a Finding of No Significant Impact.

Nevada Test Site and Off-Site Locations in the State of Nevada (DIRS 101811-DOE 1996, all) described existing and projected future actions at the Test Site. That EIS was followed by a *Supplement Analysis for the Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 162638-DOE 2002, all). Table 8-4 is a summary of the Nevada Test Site environmental assessments identified since the issuance of the Yucca Mountain FEIS.

Table 8-4. Environmental assessments identified since completion of the Yucca Mountain FEIS for the Nevada Test Site.

Title	Description
Environmental Assessment for Relocation of Technical Area 18 capabilities and materials from the Los Alamos National Laboratory to the NTS (DIRS 162639-DOE 2002, all)	DOE completed relocation of Technical Area 18 operational capabilities and materials from the Los Alamos National Laboratory to the Nevada Test Site in November 2005. Relocation included the transport of about 2.4 metric tons (2.6 tons) of special nuclear material and approximately 10 metric tons (11 tons) of natural and depleted uranium and thorium, as well as support equipment, some of which would have radioactive contamination, associated with the operations. A Finding of No Significant Impact was issued.
Environmental Assessment for Defense Logistics Agency transfer of waste to DOE and Finding of No Significant Impact (DIRS 172280-DLA 2003, all) (DIRS 172281-DOD 2003, all)	The Defense Logistics Agency of the Department of Defense issued an environmental assessment of its proposal to transfer thorium nitrate from the Defense National Stockpile Center to DOE for disposal as a low-level radioactive waste at the Nevada Test Site. The Agency issued a Finding of No Significant Impact in November 2003 (DIRS 172281-DOD 2003, all). The Defense Logistics Agency made eight shipments of low-level thorium waste [about 310 cubic yards (10,800 cubic feet)] in 2004 (DIRS 182346-DOE 2005, all).

8.1.2.4 U. S. Department of Energy

DOE is completing several environment impact statements for proposals that can be considered reasonably foreseeable future actions.

8.1.2.4.1 *Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership*

DOE is preparing the *Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership* (DOE/EIS-0396). The Global Nuclear Energy Partnership (GNEP) would encourage expansion of domestic and international nuclear energy production while reducing nuclear proliferation risks, and reduce the volume, thermal output, and radiotoxicity of spent nuclear fuel before disposal in a geologic repository (72 FR 331, January 4, 2007). DOE anticipates that its Programmatic EIS will evaluate a range of alternatives including a proposal to recycle spent nuclear fuel and separate many of the high-heat fission products and the uranium and transuranic components. The full implementation of GNEP would involve the construction and operation of advanced reactors, which would be designed to generate energy while destroying the transuranic elements. DOE also anticipates evaluating project-specific proposals to construct and operate an advanced fuel-cycle research facility at one or more DOE sites.

The United States uses a “once through” fuel cycle in which a nuclear power reactor uses nuclear fuel only once, and then the utility places the spent nuclear fuel in storage while awaiting disposal. GNEP would establish a fuel cycle in which the uranium and transuranic materials would be separated from the spent nuclear fuel and reused in thermal and/or advanced nuclear reactors. GNEP would not diminish in any way the need for the nuclear waste disposal program at Yucca Mountain, because under any fuel-recycling scenario, high-level radioactive waste will continue to be produced and require disposal.

DOE anticipates that by about 2020 the commercial utilities will have produced about 86,000 MTHM of spent nuclear fuel, which exceeds DOE’s disposal limit of 63,000 MTHM of commercial spent nuclear fuel for the Yucca Mountain Repository. If DOE decided in a GNEP Record of Decision to proceed with its proposal to recycle spent nuclear fuel, the Department anticipates that the necessary facilities would not commence operations until 2020 or later. Although the concept of recycling spent nuclear fuel has not yet been implemented and the capacity of a separations facility has not been determined, one or more separations facilities could be designed with a total capacity sufficient to recycle the spent nuclear fuel discharged by commercial utilities. Consequently, the Department believes there would be no change in the spent nuclear fuel and high-level radioactive waste inventory analyzed under the Proposed Action of this Repository SEIS (i.e., 63,000 MTHM of commercial spent nuclear fuel, which could include about 280 canisters of commercial high-level radioactive waste from the West Valley Demonstration Project, and 7,000 MTHM of DOE spent nuclear fuel [about 3,200 canisters] and high-level radioactive waste [about 9,300 canisters]).

Overall, development of a GNEP fuel cycle has the potential to decrease the amount (number of assemblies) of spent nuclear fuel that would require geologic disposal, but could increase the number of canisters of high-level radioactive waste requiring disposal in a geologic repository in the longer term. Consequently, recycling of commercial spent nuclear fuel could affect the nature of the inventory that represents the balance of Inventory Module 1 (i.e., commercial spent nuclear fuel in amounts greater than 63,000 MTHM). Nevertheless, given the uncertainties inherent at this time in estimating the amount of spent nuclear fuel and high-level radioactive waste that would result from full or partial implementation of GNEP, this Repository SEIS analyzes the transportation and disposal of about 130,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel and about 35,780 canisters of high-level radioactive waste (Inventory Module 1). Section 8.1.2.1 provides the basis for the estimates of the inventory in Module 1.

8.1.2.4.2 *Disposal of Greater-Than-Class-C Low-Level Radioactive Waste Environmental Impact Statement*

DOE is preparing the *Disposal of Greater-Than-Class-C Low-Level Radioactive Waste Environmental Impact Statement* (DOE/EIS-0375) (72 FR 40135, July 23, 2007). This EIS will address the disposal of wastes with concentrations greater than Class C, as defined in U.S. Nuclear Regulatory Commission (NRC) regulations at 10 CFR Part 61, and DOE Low-Level Radioactive Waste and transuranic waste having characteristics similar to Greater-Than-Class-C waste and that otherwise do not have a path to disposal. DOE proposes to evaluate alternatives for Greater-Than-Class-C low-level waste and Greater-Than-Class-C-like waste (also referred to as Special-Performance-Assessment-Required waste; Section 8.1.2.1) disposal in a geologic repository; in intermediate depth boreholes; and in enhanced near surface facilities. Candidate locations for these disposal facilities are the Idaho National Laboratory; the Los Alamos National Laboratory and Waste Isolation Pilot Plant in New Mexico; the Nevada Test Site and the proposed Yucca Mountain Repository; the Savannah River Site in South Carolina; the Oak Ridge Reservation in Tennessee; and the Hanford Site in Washington. DOE will also evaluate disposal at generic commercial facilities in arid and humid locations. This Repository SEIS evaluates the potential cumulative impacts of disposal of these wastes at Yucca Mountain as a reasonably foreseeable action, which is referred to as Inventory Module 2.

8.1.2.4.3 *Complex Transformation Supplemental Programmatic EIS*

DOE is currently preparing the Complex Transformation Supplemental PEIS (formerly known as the Complex 2030 Supplemental PEIS; DOE/EIS-0236-S4; 71 FR 61731, October 19, 2006). This supplemental PEIS will analyze the environmental impacts from the alternatives affecting the continued transformation of the U.S. nuclear weapons complex. Part of the proposed action is to identify one or more sites for the performance of National Nuclear Safety Administration flight test operations. Existing U.S. Department of Defense and DOE test ranges (for example, the White Sands Missile Range in New Mexico and the Nevada Test Site) would be alternatives to the continued operation of the Tonopah Test Range in Nevada. The Complex Transformation Supplemental PEIS also evaluates alternatives that would relocate to the Nevada Test Site activities that involve plutonium manufacturing, research and development, and storage; uranium manufacturing, research and development, and storage; weapons assembly and disassembly; and hydrodynamic testing.

8.1.2.4.4 *Programmatic EIS To Designate Energy Corridors on Federal Land*

To identify appropriate right-of-way corridors throughout the western United States, including Nevada, DOE and the Bureau of Land Management are co-lead agencies in preparing a programmatic EIS on the designation of energy corridors on federal land in the 11 western states (70 FR 56647, September 28, 2005). The proposed action is to designate corridors for oil, gas, and hydrogen pipelines and electricity transmission and distribution facilities. The states are Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Based on information and analyses developed, DOE and the Bureau of Land Management, as well as its federal cooperating agencies (U.S. Forest Service and U.S. Department of Defense) might amend their relevant land use plans. Until the development of the corridors analysis, the possibility of cumulative impacts, if any, with the Yucca Mountain Project is unknown.

8.1.2.5 Nye County

Nye County is proposing several projects that can be considered as reasonably foreseeable future actions.

8.1.2.5.1 *Yucca Mountain Project Gateway Area Concept Plan*

Nye County has completed a Yucca Mountain Project Gateway Area Concept Plan with proposed land use designations for the area around the entrance to the proposed repository site (DIRS 182345-Giampaoli 2007, all). This report presents Nye County's proposed multiphase land use plan for the portion of the town of Amargosa Valley that is adjacent to and near the site entrance area. Nye County proposed this plan to ensure that land development occurs in an orderly manner and to increase opportunities for industrial and commercial development consistent with the repository program. Nye County views this plan as a starting point for development of the infrastructure, institutional capacity, and facilities to offset the potential impacts associated with the repository while also benefiting the repository program. The county developed the plan to use and manage existing initiatives while expanding and improving the area. It states the purposes of the plan as follows:

- Describe key objectives and methods to manage the expected impacts of repository-related activities, which would include growth in neighboring towns,
- Review existing conditions and identify necessary planning and infrastructure improvements,
- Review financial options for land and utility development, and
- Present a land use concept to ensure orderly and compatible development for the area around the repository site entrance.

8.1.2.5.2 *Desert Space and Science Museum*

The Yucca Mountain FEIS evaluated the proposed museum that the Nevada Science and Technology Center, LLC, would construct and operate under lease from Nye County. Nye County would construct infrastructure and oversee development of industrial, commercial, recreational, and public purpose facilities on the adjacent 1.4 square kilometers (350 acres). The U.S. Fish and Wildlife Service issued a notice of availability for the "Nye County Habitat Conservation Plan for Lands Conveyed at Lathrop Wells, NV" (67 FR 39737), which includes the proposed museum and the adjacent development. In total, 3.3 square kilometers (823.22 acres) of land would transfer from the Bureau of Land Management to Nye County, of which the county would develop 0.4 square kilometer (99 acres) for the proposed facilities and manage the remaining area for natural resource values and desert tortoise habitat (DIRS 182804-Maher 2006, all). The U.S. Fish and Wildlife Service has made a preliminary determination that approval of the Habitat Conservation Plan qualifies as a categorical exclusion under NEPA.

8.1.2.5.3 *U.S. Highway 95 Technology Corridor*

Nye County has outlined a strategy for a Technology Corridor along U.S. Highway 95 (DIRS 182841-Nye County 2007, all). The corridor extends from Indian Springs in Clark County in the south to Tonopah in the north, passing through the Pahrump Valley, Mercury (entrance to the Nevada Test Site), Amargosa Valley, Beatty, and Goldfield. Nye County would like to increase industrial space to accommodate new high technology businesses by completing the Amargosa Valley Science and Technology Park at Lathrop Wells; assisting Beatty to adaptively reuse the Barrick Bullfrog site for new industry; and encourage Pahrump to facilitate a business park for the Pahrump Valley. Nye County's goals for the Technology Corridor are to change economic diversity of the region's industries; transform the regional economy to one more closely associated with national trends; and increase the presence of green energy industry in the region.

8.1.2.6 Private Fuel Storage at Skull Valley

A Federal Register Notice on February 28, 2006 shows that the U.S. Nuclear Regulatory Commission (NRC) issued a license to the proposed Private Fuel Storage facility on the Reservation of the Skull Valley Band of Goshute Indians in Tooele County, Utah (71 FR 10068, February 28, 2006). However, there is uncertainty if the privately owned project will proceed because of a failure to lease the site or obtain the necessary right-of-way access across federally managed land. The NRC prepared the *Final Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (DIRS 157761-NRC 2001, all). The Bureau of Indian Affairs disapproved the proposed lease for the facility on trust land in its Record of Decision on September 7, 2006 (DIRS 181684-Carson 2006, p. 29).

Concurrent with the Bureau of Indian Affairs Record of Decision, the Bureau of Land Management issued a Record of Decision that disapproved the Private Fuel Storage application for the right-of-way for the proposed rail spur for the facility (DIRS 181685-Calvert 2006, p. 1). The Bureau determined that the Private Fuel Storage right-of-way was not in the public interest. In a comment on this decision, the Bureau of Indian Affairs concluded that Private Fuel Storage would have to find some other method for the transport of spent nuclear fuel to the proposed facility. DOE does not expect cumulative impacts from this action with the Proposed Action for this Repository SEIS.

8.2 Cumulative Preclosure Impacts in the Proposed Yucca Mountain Repository Region

This section describes preclosure cumulative impacts during the construction, operation and monitoring, and closure of the proposed repository in the regions of influence for the resources the repository could affect and updates information from Chapter 8 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 8-1 to 8-116).

DOE has organized the analysis of cumulative impacts by resource area. As necessary, the discussion of each resource area includes cumulative impacts from Inventory Module 1 or 2; from other federal, non-federal, and private actions; and from the combination of Inventory Modules 1 and 2 and other federal, non-federal, and private actions.

8.2.1 LAND USE AND OWNERSHIP

Impacts to the ownership, management, and use of the analyzed land withdrawal area described in Chapter 4, Section 4.1.1, of this Repository SEIS would not change due to Inventory Module 1 or 2. The amount of land necessary for surface facilities would increase somewhat for Module 1 or 2 because of the larger area for excavated rock storage and additional ventilation shafts for the larger repository. This would have no substantial cumulative land use or ownership impact.

To identify and quantify cumulative impacts for land use, DOE evaluated actions that had occurred or could occur within an 80-kilometer (50-mile) radius of the repository. The only quantitative change in land use impacts from other federal, non-federal, and private actions from the Yucca Mountain FEIS would be a decrease in land disturbance for the Desert Space and Science Museum from 1.8 square kilometers (440 acres) to 0.40 square kilometer (100 acres). Changes in impacts from the continued use of the Nevada Test Site and the Nevada Test and Training Range would be unlikely. The Nye County Yucca Mountain Project Gateway Area Concept Plan presents a land use concept to ensure orderly and compatible development for the area around the repository site entrance (DIRS 182345-Giampaoli 2007, all). The Bureau of Land Management has designated approximately 23.3 square kilometers (9 square miles) of land in the town of Amargosa Valley adjacent to the repository site entrance for disposal to private use, indicating that the land has limited public use. The county proposed this plan to ensure that land development would occur in an orderly manner and increase the opportunities for industrial and commercial development consistent with the repository program. Nye County views this plan as a starting point for development of the infrastructure, institutional capacity, and facilities to support the Yucca Mountain Repository.

8.2.2 AIR QUALITY

The cumulative preclosure nonradiological impacts to air quality would essentially be the same as those for the Proposed Action in Chapter 4, Section 4.1.2, of this Repository SEIS. In summary, construction, operation and monitoring, and closure of the proposed repository would have small impacts on regional air quality for Inventory Module 1 or 2.

The activities that produced releases of criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter) would be roughly the same for Inventory Module 1 or 2 as those described for the Proposed Action (Section 4.1.2). The only changes would be the increased land disturbance and particulate matter generated for the larger area for the excavated rock storage pile and additional ventilation shafts from the larger subsurface repository. DOE would monitor the excavated rock storage pile, ventilation shafts, and other areas to ensure compliance with applicable air quality standards throughout the construction, operations, monitoring, and closure periods.

8.2.2.1 Construction

The repository construction period for Inventory Module 1 or 2 would produce the same levels of all pollutants and cristobalite because the amount of surface or subsurface construction during this 5-year period would be constant. The additional excavation necessary for Module 1 would occur during the operations period. The land disturbance outside the analyzed land withdrawal area and near the boundary of the land withdrawal area would not change. The air concentrations would still be less than the applicable regulatory limits, as reported in Chapter 4, Section 4.1.2.

8.2.2.2 Operation and Monitoring

The operations period for Inventory Module 1 or 2 would produce the same levels of gaseous pollutants but slightly higher concentrations of particulate matter and cristobalite. During the operations period, the excavated rock storage pile for Inventory Module 1 or 2 would contain approximately twice the amount of excavated rock as those for the Proposed Action. This could increase the amount of particulate matter with an aerodynamic diameter of 10 micrometers or less (about 0.0004 inch) (PM_{10}) released into the air and increase the PM_{10} concentration. However, due to the distance between the excavated rock storage pile and the boundary of the analyzed land withdrawal area, the PM_{10} concentration from the rock pile would still be significantly less than the regulatory limit. The cristobalite concentration would be less than 0.05 percent of the regulatory limit. The amount of land disturbed by ventilation shafts would increase.

As shown in Chapter 4, Section 4.1.2, all pollutant concentrations would be less than the applicable regulatory limits for the Proposed Action during the operations period. Because the development of the emplacement drifts for Module 1 or 2 would take additional time in comparison to that for the Proposed Action, these releases of criteria pollutants would occur over a longer period than those for the Proposed Action.

During the subsequent monitoring and maintenance activities, the concentrations would decrease considerably and would be the same as those reported in Chapter 4, Section 4.1.2.

8.2.2.3 Closure

Closure of the proposed repository for Inventory Module 1 or 2 could produce comparable, but slightly higher, concentrations of gaseous pollutants, particulate matter, and cristobalite than those estimated for the Proposed Action. The concentrations would be much less than the applicable regulatory limits. With Inventory Module 1 or 2, the amount of backfill necessary would be larger than that for the Proposed Action, and the size of the excavated rock storage pile to reclaim would be larger. The duration of the closure period for Inventory Module 1 or 2 would be longer than that of the Proposed Action, which could result in minor changes in the air concentrations between the Proposed Action and Inventory Module 1 or 2.

As in the Yucca Mountain FEIS, other reasonably foreseeable actions would be unlikely to have cumulative impacts with the repository or Modules 1 or 2 because they would be sufficiently far away that plumes would have limited potential for overlap. Further, the responsible agencies would take measures for each action to minimize regional air quality impacts. Repository activities would have no effect on air quality in the Las Vegas Valley air basin, which is a nonattainment area for carbon monoxide and PM_{10}, because the basin is approximately 120 kilometers (75 miles) southeast of the proposed repository site. Section 8.2.7 evaluates radiological air quality cumulative impacts.

8.2.3 HYDROLOGY

The cumulative preclosure potential impacts to surface waters and groundwater from Inventory Module 1 or 2 and other federal, non-federal, or private actions would be similar to those described in Section 8.2.3.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 8-39 to 8-40), which this section incorporates by reference and summarizes.

8.2.3.1 Inventory Module 1 or 2

8.2.3.1.1 *Surface Water*

Potential surface-water impacts from Inventory Module 1 or 2 would be relatively minor and would include the following:

- Introduction and movement of contaminants,
- Changes to runoff or infiltration rates, and
- Alterations of natural drainage.

Introduction and Movement of Contaminants
Inventory Module 1 or 2 would result in essentially no change in the potential for soil contamination during the construction, operation and monitoring, and closure periods. Neither the types of contaminants nor the operations that could involve spills or releases would change, but the operations would last longer. Similarly, there would be no change in the threat of flooding to cause contaminant releases.

Changes to Runoff or Infiltration Rates
Inventory Module 1 or 2 would require the disturbance of additional land, primarily as a result of the requirement for more area for the excavated rock storage pile and the need to construct additional ventilation shafts for the subsurface area. The additional land disturbance would be small in comparison to the total 9 square kilometers (2,300 acres) that the Proposed Action without Inventory Module 1 or 2 would disturb. This increase in disturbed land would be a relatively small portion of the natural drainage areas and would make little difference in the amount of water that soaked into the ground or reached the intermittently flowing drainage channels, particularly because most of the additional land disturbance (for the excavated rock storage pile) would be in areas where storm water detention ponds would control runoff. Disturbed areas not covered by structures would slowly return to conditions similar to those of the surrounding undisturbed ground.

Alterations of Natural Drainage
No additional actions or land disturbances from Inventory Module 1 or 2 would involve a potential to alter noteworthy natural drainage channels in the area beyond those the Proposed Action alters. The excavated rock storage pile and its increased size for Module 1 or 2 would be in an area already altered

and controlled through the installation of collection ditches and storm water detention ponds. Potential impacts to floodplains would be the same as those described for the Proposed Action (Chapter 4, Section 4.1.3.1.4). Construction could involve the placement of structures, facilities, or roadways in or over drainage channels or their associated floodplains (or flood zones) and could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash (also known as Dune Wash), Drill Hole Wash, and Midway Valley Wash (also known as Sever Wash) at Yucca Mountain.

8.2.3.1.2 *Groundwater*

Potential groundwater impacts from Inventory Module 1 or 2 would relate to the following:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository or decrease the amount of recharge to the aquifer,

- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository, and

- The potential for water demands for the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users.

Changes to Infiltration and Aquifer Recharge

Under Inventory Module 1 or 2, DOE anticipates changes due to infiltration and recharge rates in three areas—an increase in the size of the excavated rock storage pile, an increase in the number of ventilation shaft operations areas, and an extended scope for subsurface activities. The following paragraphs discuss these items.

Additional land disturbance would result from the continued growth of the excavated rock storage pile. Although the rock pile could have different infiltration rates than undisturbed ground, it probably would not be a recharge location because of the extended depth of unconsolidated material, and it probably would not cause a large change in the amount of water that would otherwise reach recharge areas such as drainage channels.

Increased land disturbance would result from the additional ventilation shaft operation areas and the access roads that DOE would need for the increased size of the repository footprint. These areas of disturbance would be primarily on steeper terrain, uphill from the portal areas, where unconsolidated material is probably thin and where disturbances could expose fractured bedrock and increase infiltration rates. However, road material or equipment pads would cap much of the disturbed area, and the amount of disturbed land would be small in comparison to the surrounding undisturbed area.

Underground activities and their associated potential to increase recharge due to their use of water would be basically the same as those described for the Proposed Action, except emplacement drift construction could take up to twice as long to complete in comparison to the Proposed Action. As described for the Proposed Action, the quantities of water in the subsurface that ventilation or pumping did not remove to the surface by ventilation or pumping, and thus was available for recharge, would be small.

Potential for Contaminant Migration to Groundwater Zones

Neither Inventory Module 1 nor 2 would involve additional actions likely to increase the potential for contaminant releases to the environment, although actions, in general, would last longer.

Potential to Deplete Groundwater Resources

Anticipated annual water demand for Inventory Module 1 or 2 would be the same as or very similar to that for the Proposed Action, but the operations period, when both emplacement and subsurface development were occurring, could last approximately twice as long. DOE based the repository water demand estimates described in Chapter 4, Section 4.1.3.2 on a maximum design throughput of the surface facilities of about 3,000 MTHM per year of spent nuclear fuel and high-level radioactive waste. Because Inventory Module 1 or 2 would roughly double the amount of materials the facilities processed, it would take about twice as long and the associated water demand, already based on a maximum operational rate, would stay the same. The extended duration of this period (when subsurface development and emplacement were both ongoing) would result in a significant increase in the total water demand for the action, but the annual demand would be unlikely to change in any appreciable amount. As described in Section 4.1.3.2, water demand during this period would probably range from 130,000 to 200,000 cubic meters (100 to 160 acre-feet) per year. A notable change in water demand would be unlikely during the construction period or during the 5 years immediately after the construction period when some building on the surface would still be under way, the subsurface area would still be under construction, and emplacement would be ongoing.

As noted in Chapter 4, Section 4.1.3.2 for the repository portion of the Proposed Action, water demand for the monitoring and closure periods would probably remain unchanged from those identified in the Yucca Mountain FEIS. As in the operations period, closure would probably take longer with the Module 1 or 2 inventory, but annual demand rates during closure would probably be the same or very similar.

Potential impacts to water resources under Inventory Module 1 or 2 would be very similar to those under the Proposed Action because the annual water demand would change little, and the best understanding of the groundwater resource is that it replenishes on an annual basis as gauged by the perennial yield of the groundwater basin. Under Module 1 or 2, the highest annual water demand would be below estimates of perennial yield for the Jackass Flats hydrographic area; this would include the lowest estimated value of perennial yield [720,000 cubic meters (580 acre-feet)] for the western two-thirds of this hydrographic area (Chapter 3, Section 3.1.4.2.2). Chapter 2, Section 2.3 contains more information on regional groundwater use and demand for the combined repository and rail actions.

8.2.3.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

As in the Yucca Mountain FEIS, other reasonably foreseeable actions would be unlikely to have cumulative impacts for the repository or Modules 1 or 2. Potential impacts to groundwater from the Proposed Action, including both repository and rail actions as described in Chapter 2, Section 2.3, and from Inventory Module 1 or 2 would be small and limited to the immediate vicinity of land disturbances from the action. The exceptions to this could be the potential impact from water demands on groundwater resources and potential impacts from contaminants in groundwater. With these exceptions, other federal, non-federal, or private action effects would have to occur in the same region of influence to be cumulative with those from the Proposed Action or Inventory Module 1 or 2; no currently identified actions meet this criterion.

The remainder of this discussion addresses potential impacts to groundwater resources from water demand. The discussion of impacts to groundwater resources in Chapter 4, Section 4.1.3.2 includes ongoing water demands from Area 25 of the Nevada Test Site. Area 25 is the proposed location of the primary repository surface facilities. It is also the location of wells J-12, J-13, and the C-well complex, which would provide water for the Proposed Action and for ongoing Nevada Test Site activities in this area. During the 7-year period from 2000 to 2006, the average Test Site water withdrawal from the Jackass Flats hydrographic area for the Area 25 activities has been about 83,000 cubic meters (67 acre-feet) per year (DIRS 181232-Fitzpatrick-Maul 2007, all). In a 2002 analysis, DOE indicated there were no planned expansions of existing operations on the Test Site that would affect water use, but that future programs could involve additional water use (DIRS 162638-DOE 2002, pp. 4-18 and 4-19). DOE assumed that this recent use represents a reasonable estimate of Nevada Test Site water demand, at least in the near term (5 to 10 years). However, it recognized that the Test Site demand could increase at some time in the more distant future, but water demand for the Proposed Action would decrease over time.

Water demand from rail and repository actions at the start of construction activities under Inventory Module 1 or 2 combined with the baseline demands from Nevada Test Site activities could exceed the lowest value of perennial yield estimated for the western two-thirds of the hydrographic area, but for only 1 year. Estimated water demand for that year (which includes the demand for Nevada Test Site activities in Area 25 and for the rail construction that would occur in the Jackass hydrographic area) would be approximately 740,000 cubic meters (600 acre-feet) in comparison to the lowest estimate of perennial yield of 720,000 cubic meters (580 acre-feet) for the western two-thirds of the hydrographic area. Other than in this single year, the combined water demands would be below the lowest estimate of perennial yield. None of the water demand estimates would approach the high estimate of perennial yield for the entire Jackass Flats hydrographic basin, which is 4.9 million cubic meters (4,000 acre-feet) (Chapter 3, Section 3.1.4.2.2). Potential impacts to groundwater resources from this combined demand would be no different than those described in Chapter 2, Section 2.3 and in more detail in Chapter 4, Section 4.1.3.2; that is, some decline in the water level could be likely near the production wells, and water elevation decreases at the town of Amargosa Valley would probably be no more than 0.4 to 1.1 meter (1.2 to 3.6 feet) (Section 4.1.3.2). The reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area would be less than the quantity of water actually withdrawn from the upgradient area because there would probably be minor changes in groundwater flow patterns as the water level adjusted to the withdrawals. Groundwater flow models predict that the reduction in underflow to the Amargosa Desert would be no higher than 160,000 to 180,000 cubic meters (130 to 150 acre-feet) per year, even with the assumption of a long-term groundwater withdrawal rate of 530,000 cubic meters (430 acre-feet) per year (Section 4.1.3.2).

The Supplement Analysis for the Nevada Test Site FEIS (DIRS 162638-DOE 2002, pp. 4-18 and 4-19) indicated there are no planned expansions of present operations that would affect water use. It did, however, identify potential future projects that, if implemented, could involve additional Nevada Test Site water use. The Kistler Launch Facility might not be completed because Kistler Aerospace filed to reorganize under Chapter 11 of the U.S. Bankruptcy Code (DIRS 169260-Kistler Aerospace 2003, all). If the project does take place, it would be in Area 19 of the Nevada Test Site and could require only 3,800 to 6,800 cubic meters (3 to 5.5 acre-feet) of water per year, which would be a minor portion of the perennial yield of the Buckboard Mesa hydrographic area. Because there would be no expected effect on groundwater availability, cumulative effects from the Kistler Launch Facility would be unlikely. The Atlas Facility in Area 6 of the Nevada Test Site could require water primarily for dust suppression during construction. Its operating use of 400 cubic meters (0.32 acre-foot) per year would be minor and would not present a cumulative effect. The Advanced Accelerator applications project would use the most water of the potential projects and would be in either Area 22 or Area 25 of the Nevada Test Site (DIRS 162638-DOE 2002, p. 3-8). This project could require an estimated 4.9 million cubic meters (3,900 acre-feet) for construction and system initialization and about 490,000 to 980,000 cubic meters (390 to 790 acre-feet) per year thereafter. If this project was implemented, particularly in Area 25, its water demand could be significant and cumulative with the Proposed Action, although the Supplement Analysis indicated that its water demand would be sustainable by existing groundwater resources (DIRS 162638-DOE 2002, p. 4-19).

Cumulative demands on the Jackass Flats hydrographic area could have long-term impacts on water availability in the downgradient aquifers beneath the Amargosa Desert. The groundwaters in these areas are hydraulically linked, but the exact nature and extent of the links is a matter of study and some speculation. However, the amount of water being withdrawn in the Amargosa Desert [averaging about 16 million cubic meters (13,000 acre-feet) per year between 2000 and 2004 (Chapter 3, Section 3.1.4.2.1)] is much greater than the quantities being considered for withdrawal from Jackass Flats. If water pumped from Jackass Flats affected water levels in the Amargosa Desert, the impacts would be small in comparison to those caused by local pumping in that area.

The Nye County Yucca Mountain Project Gateway Area Concept Plan is a land use concept to ensure orderly and compatible development for the area around the repository site entrance (DIRS 182345-Giampaoli 2007, all). Development could affect available water; Nye County proposed this plan to ensure that development occurred in an orderly manner consistent with the proposed repository land use.

8.2.4 BIOLOGICAL RESOURCES

The cumulative preclosure impacts to biological resources would be similar to those for the Proposed Action in Chapter 4, Section 4.1.4, of this Repository SEIS. Those impacts would occur primarily as a result of site clearing, placement of material in the excavated rock storage pile, habitat loss, and loss of individuals of some animal species during site clearing and from vehicle traffic. Inventory Module 1 or 2 would require disturbance of biological resources in a slightly larger area than that disturbed under the Proposed Action, primarily because the excavated rock storage pile would be larger.

The Nye County Yucca Mountain Project Gateway Area Concept Plan (DIRS 182345-Giampaoli 2007, all) anticipates potential effects on some species of plants, fish, and wildlife resources. Because this is only a plan, specific impacts cannot be determined.

8.2.5 CULTURAL RESOURCES

The cumulative preclosure impacts to cultural resources could increase slightly from those reported for the Proposed Action (Chapter 4, Section 4.1.5) due to a slight increase in land disturbance associated with Inventory Module 1 or 2. The emplacement of either module would require small additional disturbances to land in areas surveyed during site characterization activities and an increase in the time of operation. Because repository construction, operation and monitoring, and closure would be federal actions, DOE would identify and evaluate cultural resources, as required by Section 106 of the *National Historic Preservation Act*, and would take appropriate measures to avoid or mitigate adverse impacts to such resources. As a consequence, archaeological information from artifact retrieval during land disturbance would contribute additional cultural resources information to the regional database for understanding past human occupation and use of the land.

The Nye County Yucca Mountain Project Gateway Area Concept Plan (DIRS 182345-Giampaoli 2007, all) is for managing development of the area south of the analyzed land withdrawal area. If implemented, there could be potential impacts to cultural resources; however, there are no currently identified specific actions that would have a noticeable cumulative impact on socioeconomics.

8.2.6 SOCIOECONOMICS

The cumulative preclosure impacts to socioeconomics would be similar to those in Chapter 4, Section 4.1.6, for the Proposed Action. The increased inventory associated with the modules would not result in a larger number of employees, but would result in a longer duration of the operations period. The annual socioeconomic impacts would occur for a longer period.

Additional cumulative impacts from other reasonably foreseeable federal, non-federal, or private actions could probably be from actions at the Nevada Test Site, as discussed in the Yucca Mountain FEIS. Nye County acknowledges there could be potential impacts to the socioeconomics of the region in the Yucca Mountain Project Gateway Area Concept Plan (DIRS 182345-Giampaoli 2007, all). This plan, as stipulated earlier, is for management of the development of the area south of the analyzed land withdrawal area. There are no currently identified specific actions that would have a noticeable cumulative impact on socioeconomics.

8.2.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

8.2.7.1 Industrial Hazards

The preclosure cumulative impacts to nonradiological occupational health and safety would increase proportionately with the number of full-time equivalent worker years on the project. Because the inventory of spent nuclear fuel and high-level radioactive waste could be approximately twice that of the Proposed Action (Section 4.1.7.1), the number of full-time equivalent worker years during the operations period could probably also double under Modules 1 and 2. As presented in Section 4.1.7.1, the project would require one-half of the estimated workforce for the Proposed Action during the operations period. Therefore, the total estimated impacts from industrial hazards could increase by 50 percent over the impacts presented in Section 4.1.7.1.

Nye County Public Safety Report (DIRS 182710- NWRPO 2007, all) addresses Nye County's concerns and provides recommendations on public safety issues. Nye County recommends a comprehensive and integrated approach for public safety services with DOE, including fire, emergency, medical, and law enforcement services.

8.2.7.2 Radiological Impacts

This section discusses preclosure radiological health and safety impacts to workers and to members of the public from construction, operation and monitoring, and closure activities at the Yucca Mountain site for Inventory Module 1 or 2. Appendix D, Section D.3 contains the approach and methods DOE used to estimate radiological health and safety impacts and detailed radiological impact results for the Proposed Action.

The radiological characteristics of the spent nuclear fuel and high-level radioactive waste for Inventory Module 1 or 2 would be the same as those for the Proposed Action. However, there would be more material to emplace. As described in Appendix A of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. A-1 to A-71), the radioactive inventory of Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste would be much less than that for spent nuclear fuel and high-level radioactive waste. Therefore, the subsurface emplacement of the material in Inventory Module 2 could increase radiological impacts to workers only slightly over those for Module 1 as referenced in the Yucca Mountain FEIS, Chapter 8, Section 8.2.7.2.

The primary parameters that would affect the magnitude of worker health and safety impacts between the Proposed Action and Inventory Module 1 or 2 would be the periods DOE required to perform the work and the numbers of workers for the different periods. For the public, the principal changes in parameters that would affect the magnitude of the health impact estimates would be the length of the various periods and the rate at which air would exhaust from the repository. The exhaust rate of the repository ventilation system would affect the worker exposures from manmade and radon-222 concentrations and the quantity of radionuclides released to the environment. Appendix D, Section D.3.1, discusses potential releases of radon-222 and manmade radionuclides during the project periods.

Table 8-5 compares estimates of radiological impacts to workers for each repository analytical period and for the entire project duration for the Proposed Action and Inventory Module 1 or 2.

The estimated radiological impacts would include potential doses and radiological health impacts to involved workers, noninvolved workers, and the total for all workers. Radiological health impacts for maximally exposed individuals would be the increase in the probability of a latent cancer fatality from the radiation dose received. Radiological health impacts for exposed populations would be the estimated number of latent cancer fatalities that resulted from the collective radiation dose received. The calculated values for latent cancer fatalities for repository workers during the construction, operation and monitoring, and closure periods for Module 1 or 2 could be about 9 fatalities. These are about double those for the Proposed Action (4.4 fatalities). Most of the total worker radiation dose would be from the receipt and handling of spent nuclear fuel during the operations period. Radiation exposure from inhalation of radon-222 and its decay products from radiation that emanated from the subsurface would be contributors to the total dose. DOE identified no other activities in the area that could cause cumulative radiological impacts to repository workers.

Table 8-6 summarizes estimates of radiological impacts to the public for each repository activity period and the entire project duration for the Proposed Action and Inventory Module 1 or 2. It lists estimated radiation doses and health effects for the offsite maximally exposed individual and the potentially exposed population.

The radiological doses and health impacts would result primarily from exposure of the public to naturally occurring radon-222 and its decay products released from the subsurface facilities in ventilation exhaust air. The calculated increase in probability that the maximally exposed individual would experience a latent cancer fatality would be less than 0.0006 for Module 1 or 2. The estimated increase in the number of latent cancer fatalities could be 17 for the exposed population within 80 kilometers (50 miles) over the entire project duration.

Table 8-5. Radiation doses and radiological health impacts to workers for each activity period and the entire project duration.

Worker group and impact category	Construction	Operation	Monitoring	Closure	Entire project
Proposed Action					
Maximally exposed worker					
Dose (rem)					
Involved	0.49	30	13	1.6	30
Noninvolved	0.052	0.32	0.21	0.028	0.32
Probability of latent cancer fatality					
Involved	0.00029	0.018	0.0078	0.0010	0.018
Noninvolved	0.000031	0.00019	0.00012	0.000017	0.00019
Worker population					
Collective dose (person-rem)					
Involved	33	5,800	890	400	7,100
Noninvolved	4.7	230	26	18	280
Nevada Test Site noninvolved	0.12	9.2	8.9	1.2	19
Total	38	6,000	930	420	7,400
Number of latent cancer fatalities					
Involved	0.02	3.5	0.54	0.24	4.2
Noninvolved	0.0028	0.14	0.016	0.011	0.17
Nevada Test Site noninvolved	0.000074	0.0055	0.0053	0.00073	0.012
Total	0.023	3.6	0.56	0.25	4.4
Inventory Module 1 or 2					
Maximally exposed worker					
Dose (rem)					
Involved	0.49	30	13	3.3	30
Noninvolved	0.05	0.65	0.43	0.059	0.65
Probability of latent cancer fatality					
Involved	0.00029	0.018	0.0078	0.0020	0.018
Noninvolved	0.000031	0.00039	0.00026	0.000035	0.00039
Worker population					
Collective dose (person-rem)					
Involved	33	12,000	1,900	820	15,000
Noninvolved	4.7	480	54	37	580
Nevada Test Site noninvolved	0.12	19	18	2.5	40
Total	38	12,000	1,900	860	15,000
Number of latent cancer fatalities					
Involved	0.020	7.1	1.1	0.49	8.8
Noninvolved	0.0028	0.29	0.032	0.022	0.35
Nevada Test Site noninvolved	0.000074	0.011	0.011	0.0015	0.024
Total	0.023	7.4	1.2	0.52	9.2

For comparison, the number of latent cancer fatalities calculated for the public from Yucca Mountain construction, operation and monitoring, and closure activities for Inventory Module 1 or 2 could be about twice that estimated for the Proposed Action. Statistics published by the Centers for Disease Control and Prevention indicate that during 1998 24 percent of all deaths in the State of Nevada were attributable to cancer of some type (DIRS 153066-Murphy 2000, p. 8). Assuming this rate would remain unchanged for the projected population in 2067 of about 117,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 28,000 members of this population would be likely to die from cancer-related causes. During the project duration of 105 years, the corresponding number of cancer deaths unrelated to the project in the general population would be 42,000.

Table 8-6. Radiation doses and radiological health impacts to the public for each activity period and entire project.

Dose and health impact	Construction	Operation	Monitoring	Closure	Entire project
Proposed Action					
Maximally exposed individual					
Dose (millirem)					
Maximum annual	1.3	6.8	6.8	6.8	6.8
Total	3.8	280	270	37	480
Probability of LCF	2.3×10^{-6}	1.7×10^{-4}	1.6×10^{-4}	2.2×10^{-5}	2.9×10^{-4}
Exposed 80-kilometer population					
Collective dose (person-rem)	85	6,400	6,100	840	13,000
Number of LCFs	0.051	3.8	3.7	0.51	8
Inventory Module 1 or 2					
Maximally exposed individual					
Dose (millirem)					
Maximum annual	1.3	14	14	14	14
Total	3.8	580	560	77	990
Probability of LCF	2.3×10^{-6}	3.5×10^{-4}	3.4×10^{-4}	4.6×10^{-5}	5.9×10^{-4}
Exposed 80-kilometer population					
Collective dose (person-rem)	85	13,000	13,000	1,700	28,000
Number of LCFs	0.051	7.9	7.6	1.0	17

Note: Conversion factors are on the inside back cover of this Repository SEIS.
LCF = Latent cancer fatality.

As reported in *Nevada Test Site Environmental Report 2005* (DIRS 182285-Wills 2006, Table 8-4, operations at the Nevada Test Site resulted in a dose to the maximally exposed individual in 2005 of 0.52 millirem. The annual population doses for period 1992 to 2004 from Test Site activities were all below 0.6 person-rem per year (DIRS 182285-Wills 2006, Section 8.1.8).

With one exception, DOE identified no other federal, non-federal, or private actions with spatially or temporally coincident short-term impacts in the region of influence that would result in cumulative health and safety impacts with those of the proposed repository. Chapter 3 discusses potential radiological doses from past weapons testing at the Nevada Test Site. Residents who were present during the periods when weapons testing occurred (in particular, atmospheric weapons testing from the 1950s to the early 1960s) could have received as much as 5 rem to the thyroid from iodine-131 releases. Using a tissue-weighting factor of 0.05 as specified in Publication 60 of the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, all), this would equate to an effective dose equivalent of about 250 millirem. DOE has not added this dose to the dose to the hypothetical maximally exposed individual, but has included this information so long-term residents in the region of influence can evaluate their potential for impacts from past nuclear weapons testing. Potential radiological doses from past weapons testing at the Nevada Test Site could result in additional impacts to residents who were present during that period. Assuming the maximally exposed individual was present during the entire period in which weapons testing occurred, the maximally exposed individual dose listed in Table 8-6 could increase by as much as 250 millirem.

8.2.8 ACCIDENTS

The cumulative preclosure impacts on accidents related to Inventory Modules 1 and 2 would be the same as those for the Proposed Action. In summary, disposal of the proposed repository of Inventory Module 1 or 2 could result in a very small increase in the estimated risk from accidents described in Chapter 4, Section 4.1.8, for the Proposed Action. Workers would handle the same types of materials, but the repository operations period would be longer.

Additional cumulative impacts from other federal, non-federal, or private actions have decreased from those in the Yucca Mountain FEIS due to the likely elimination of an action—the proposed VentureStar®/ Kistler project—because Kistler filed to reorganize under Chapter 11 of the U.S. Bankruptcy Code (DIRS 169260-Kistler Aerospace 2003). DOE does not expect other federal, non-federal, or private actions in the region to have cumulative accident impacts.

8.2.9 NOISE

The cumulative preclosure impacts on noise would be the same as those in Chapter 4, Section 4.1.9, for the Proposed Action. In summary, the emplacement of Inventory Module 1 or 2 would have noise levels from the construction and operation of the repository similar to those for the Proposed Action. An increase in noise impacts from Module 1 or 2 would result only from the increased number of shipments to the site. The expected rate of receipt would be about the same as that for the Proposed Action; therefore, the impact would be an extended period that shipping would continue beyond the Proposed Action.

DOE does not expect other federal, non-federal, or private actions in the region to add measurable noise impacts to those of the Proposed Action or Inventory Module 1 or 2 because the other activities would be some distance from the proposed repository, and overall increased noise would be unlikely.

8.2.10 AESTHETICS

The cumulative preclosure impacts to aesthetics for Inventory Modules 1 and 2 would be the same as those for the Proposed Action. In summary, there would be no impacts for Inventory Module 1 or 2 beyond those described in Chapter 4, Section 4.1.10, because the profile of the repository facility would not be different as a result of implementation of these modules. There would be no difference in the appearance of the access road to facilities built outside the analyzed land withdrawal area.

Additional cumulative impacts from other reasonably foreseeable federal, non-federal, or private actions would most likely be from anticipated growth adjacent to the repository. Nye County has written the Yucca Mountain Project Gateway Area Concept Plan (DIRS 182345-Giampaoli 2007, all) to assist in managing the development of the area outside the analyzed land withdrawal area. Future development along U.S. Highway 95 would change the landscape from its current undeveloped state; however, the plan would manage this development to minimize aesthetic impacts.

8.2.11 UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

Preclosure cumulative impacts for utilities, energy, materials, and site services for the disposal of Inventory Modules 1 or 2 would have only minor differences from those in Chapter 4, Section 4.1.11, for the Proposed Action. Because the surface facilities and the annual throughput would be the same for the inventory modules, annual impacts to electricity use, fossil fuel demand, and residential water and sewer services would be the same as those for the Proposed Action, but would last for a longer operations period.

The emplacement of the larger inventories of Module 1 or 2 would require approximately twice the subsurface excavation and underground construction materials.

Additional cumulative impacts from other reasonably foreseeable federal, non-federal, or private actions would most likely be from anticipated growth adjacent to the repository. Nye County has written the Yucca Mountain Project Gateway Area Concept Plan (DIRS 182345-Giampaoli 2007, all) to assist in managing the development of the area outside the analyzed land withdrawal area. This anticipated growth could result in future use of utilities, energy, and materials. DOE does not anticipate that this additional use would result in measurable strain on the regional supplies of energy or materials.

8.2.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

Preclosure cumulative impacts from the management of repository-generated waste and hazardous materials for the disposal of Inventory Module 1 or 2 would have only minor differences from those in Chapter 4, Section 4.1.12, for the Proposed Action. Because the surface facilities and the annual throughput would be the same for the inventory modules, the annual production of all waste types would be the same as that for the Proposed Action, but would last for a longer operations period.

Additional cumulative impacts from other federal, non-federal, or private actions could occur to waste operations at the Nevada Test Site from the disposal of waste for Inventory Modules 1 and 2. The disposal of construction and demolition debris impacts would not change from those in the Yucca Mountain FEIS.

8.2.13 ENVIRONMENTAL JUSTICE

The cumulative preclosure impacts to environmental justice would be the same as those in Chapter 4, Section 4.1.13, for the Proposed Action. DOE determined there would be no high and adverse health and environmental cumulative impacts from Inventory Module 1 or 2, along with other federal, non-federal, and private actions, to the population as a whole. Further, no specific pathways were identified for minority or low-income populations. Therefore, no disproportionately high and adverse impacts to minority or low-income populations would be expected from these cumulative activities.

DOE recognizes that American Indian people who live near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on access to the site. Chapter 4, Section 4.1.3.4 discusses these views and beliefs.

8.3 Cumulative Postclosure Impacts in the Yucca Mountain Repository Region

This section updates the estimated postclosure human health and safety cumulative impact analysis of the disposal of the larger inventory projected for Inventory Modules 1 and 2 and references Chapter 8 of the

Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 8-1 to 8-116), which discusses cumulative impacts from other federal, non-federal, and private actions.

8.3.1 INVENTORY MODULE 1 OR 2 IMPACTS

The analysis of postclosure performance for Inventory Modules 1 and 2 used a scaling approach based on analyses in the Yucca Mountain FEIS, results for the Proposed Action (Chapter 5), and inventories updated since the completion of the FEIS. As discussed in Section 8.1 of the Yucca Mountain FEIS, the Module 1 inventory contained 105,000 MTHM of commercial spent nuclear fuel and the Proposed Action inventory contained 63,000 MTHM (DIRS 155970-DOE 2002, pp. 8-2 to 8-20). The first-10,000-year and the 1-million-year peak of the mean doses to individuals in the FEIS were 60 percent higher for Module 1 than for the Proposed Action (DIRS 155970-DOE 2002, Table I-13). The commercial spent nuclear fuel inventory in the FEIS for Module 1 was approximately 67 percent higher than that for the Proposed Action, which indicated approximately a linear relationship between the commercial spent nuclear fuel inventory and individual radiological impacts. Module 2 impacts added a fraction of a percent to the 1-million-year radiological impacts for the Proposed Action in the FEIS.

DOE used a bounding analysis to estimate the postclosure impacts from chemically toxic material in the Yucca Mountain FEIS. As discussed in Appendix I, Section I.6.2 of the FEIS, due to the nature of the analysis the estimated impacts were directly proportional to the number of waste packages in each inventory (DIRS 155970-DOE 2002, pp. I-54 to I-62). DOE performed a similar bounding analysis for this Repository SEIS so such proportionality would also exist.

In addition to postclosure human health impacts from radioactive and chemically toxic material releases, the other potential postclosure impact that DOE identified after repository closure would involve biological resources. Although the surface area affected by heat rise would be larger for Inventory Module 1 or 2, the amount of heat per unit area would be constant. Therefore, postclosure biological effects of Module 1 or 2 from heat generated by waste packages that could raise ground surface temperatures would be the same as those described in Chapter 5, Section 5.9 for the Proposed Action.

8.3.1.1 Radioactive and Chemically Toxic Material Scale Factors for Inventory Modules 1 and 2

The Proposed Action contains an inventory that would include 63,000 MTHM of commercial spent nuclear fuel; the Module 1 inventory would contain 130,000 MTHM (Section 8.1.2.1). The scaling factor for radiological impacts for Module 1 is proportional to the MTHM of commercial spent nuclear fuel. Therefore the scaling factor for Module 1 would be 130,000 divided by 63,000 or about 2.1. Based on the results in the Yucca Mountain FEIS, Module 2 would add less than 1 percent.

The scaling factor for chemically toxic material impacts for Module 1 or 2 would be proportional to the number of waste packages. Table 8-15 in Section 8.5 lists the estimated number of waste packages for Modules 1 and 2. The scaling factor for Module 1 is 25,700 divided by 11,200 or about 2.3 and the scaling factor for Module 2 is 26,300 divided by 11,200, also about 2.3.

8.3.1.2 Waterborne Radioactive Material Impacts

Chapter 5 and Appendix F discuss the Proposed Action postclosure impacts. Table 8-7 summarizes the impacts for the Proposed Action. The estimated impacts from Module 1 would be about twice these values and those from Module 2 would add an additional fraction of 1 percent to the Module 1 values.

Table 8-7. Impacts to the reasonably maximally exposed individual from groundwater releases of radionuclides—combined scenario classes.

	Mean		Median		95th percentile	
	Annual individual dose (millirem)	Probability of LCF[a] per year	Annual individual dose (millirem)	Probability of LCF[a] per year	Annual individual dose (millirem)	Probability of LCF[a] per year
During the first 10,000 years after repository closure	0.24	1.4×10^{-7}	0.12	7.2×10^{-8}	0.71	4.3×10^{-7}
After the first 10,000 years and up to 1 million years after repository closure	2.3	1.4×10^{-6}	0.98	5.9×10^{-7}	11	6.6×10^{-6}

a. LCF = Latent cancer fatality; assuming a risk of 0.0006 latent cancer per rem for members of the public (DIRS 174559-Lawrence 2002, p.2).

8.3.1.3 Waterborne Chemically Toxic Material Impacts

The impacts from waterborne chemically toxic materials for the Proposed Action are summarized in Table 8-8. The Yucca Mountain FEIS addressed chromium, but it has been eliminated through a screening analysis discussed in Appendix F, Section F.5.1, so Table 8-8 addresses impacts from molybdenum, nickel, and vanadium. The impacts from Module 1 are estimated to increase by a factor of 2.3 and no significant increase beyond Module 1 would be expected for Module 2.

Table 8-8. Impacts and applicable standards for waterborne chemically toxic materials release during 10,000 years after repository closure.

Material	Estimated concentration (milligram per liter)	Intake[a] (milligram per kilogram of body mass per day)	Intake standard: Oral Reference Dose (milligram per kilogram of body mass per day)
Molybdenum	0.04	0.001	0.005[b]
Nickel	0.19	0.005	0.02[c]
Vanadium	0.0001	0.000003	0.007[d]

Source: Appendix F, Section F.5.2.5.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Assuming daily intake of 2 liters (0.53 gallons) per day by a 70-kilogram (154-pound) individual.

b. DIRS 148228-EPA 1999, all.

c. DIRS 148229-EPA 1999, all.

d. DIRS 103705-EPA 1997, all.

EPA = U.S. Environmental Protection Agency.

8.3.1.4 Atmospheric Radioactive Material Impacts from Other than Volcanic Eruption

Impacts from nonvolcanic atmospheric releases are discussed in Chapter 5, Section 5.5. These releases would be extremely small. As with the Yucca Mountain FEIS it would not be expected that any significant increase of these impacts would result from Modules 1 and 2.

8.3.2 CUMULATIVE IMPACTS FROM OTHER FEDERAL, NON-FEDERAL, AND PRIVATE ACTIONS

Section 8.3.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 8-20 to 8-67) discusses the cumulative postclosure impacts from two other sources—Nevada Test Site past, present, and reasonably foreseeable future actions and Beatty low-level radioactive waste disposal and hazardous waste treatment storage and disposal facilities. There would be no additional cumulative postclosure impacts beyond those discussed in the FEIS. This section of the Repository SEIS summarizes and updates the information from the FEIS.

8.3.2.1 Nevada Test Site—Past, Present, and Reasonably Foreseeable Future Actions

The primary mission of the Nevada Test Site historically was to conduct nuclear weapons tests. Nuclear weapons testing and other activities have resulted in radioactive contamination at the Test Site. These past activities have continued potential for radioactive and nonradioactive contamination of some areas of the Test Site, including groundwater under the site. DOE evaluated these areas and the associated contamination and the potential for contamination for potential cumulative impacts with postclosure impacts from the proposed repository. Deep underground testing and greater confinement disposal categories represent the primary radionuclide inventories that could, combined with the repository inventory, result in increased cumulative impacts. After evaluation, the estimated total potential cumulative impact (Yucca Mountain impact plus Nevada Test Site impact) would be 0.24 millirem per year to the reasonably maximally exposed individual. The Test Site impact makes an insignificant contribution to the total.

New actions could also result in additional waste disposal at the Nevada Test Site. This potential new waste, in addition to the waste discussed in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, all) should result in minimal impact for waste management. The total amount of waste DOE expects to dispose of at the Site is within the bounds evaluated in the most recent EISs [Nevada Test Site EIS (DIRS 101811-DOE 1996, all) and programmatic waste management EIS (DIRS 101816-DOE 1997, all)] and would not contribute to postclosure impacts beyond those described in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 8-82 to 8-84).

8.3.2.2 Beatty Low-Level Radioactive Waste Disposal and Hazardous Waste Treatment Storage and Disposal Facilities

The low-level radioactive waste disposal facility, formerly operated by U.S. Ecology, a subsidiary of American Ecology, is 16 kilometers (10 miles) southeast of Beatty, Nevada, and 180 kilometers (110 miles) northwest of Las Vegas. This site is about 15 kilometers (9.3 miles) west of the proposed repository. The Nevada State Health Division formally accepted permanent custody of the low-level radioactive commercial waste disposal facility in a letter to American Ecology dated December 30, 1997 (DIRS 148088-AEC 1999, all). The U.S. Ecology Hazardous Waste Treatment, Storage and Disposal Facility is a *Resource Conservation and Recovery Act*-permitted facility, with engineered barriers and systems and administrative controls that minimize the potential for offsite migration of hazardous constituents. DOE has determined that cumulative postclosure impacts from the Beatty low-level radioactive waste disposal facility with the repository would be very small.

8.4 Cumulative Transportation Impacts

This section discusses the results of the cumulative impact analysis of transportation. The information in Section 8.4.1 covers cumulative impacts of the transportation of spent nuclear fuel and high-level radioactive waste from 72 commercial and 4 DOE sites to the proposed repository. Chapter 6 discusses environmental impacts of national transportation. Section 8.4.2 presents the cumulative impacts from the Rail Alignment EIS.

8.4.1 NATIONAL TRANSPORTATION

This section describes cumulative impacts from national transportation. Section 8.4.1.1 presents potential cumulative impacts from the storage and loading of spent nuclear fuel and high-level radioactive waste at commercial generator sites and DOE facilities to the proposed repository. Section 8.4.1.2 presents the potential cumulative impacts from shipment of Inventory Module 1 or 2 from commercial generator sites and DOE facilities. Section 8.4.1.3 presents potential cumulative national transportation impacts for the Proposed Action and Module 1 or 2 when combined with past, present, and reasonably foreseeable future shipments of radioactive material.

8.4.1.1 Cumulative Impacts of Storage and Loading at Generator Sites

The activities associated with the Proposed Action would include the loading of commercial spent nuclear fuel into transportation, aging, and disposal (TAD) canisters at the commercial generator sites, loading of the TAD and other canisters into rail casks, and loading of the rail casks onto rail cars. Additional related activities that could result in impacts at the generator sites include the loading of commercial spent nuclear fuel into other canisters, such as dual-purpose canisters and the storage of commercial or DOE spent nuclear fuel or high-level radioactive waste. This section describes the cumulative impacts of these related actions.

The primary cumulative impacts from these actions would be from radiation exposures of workers, fatalities from industrial accidents, and from radiation exposures of members of the public.

Table 8-9 lists the cumulative radiological impacts to workers of storage and loading at the generator sites. DOE based the estimation of impacts of loading of canisters on the same methods and data as those for loading of TAD canisters (see Appendix G). The Department based the estimates of the impacts of canister storage at the commercial generator sites on data for surveillance and maintenance of dry storage casks (DIRS 175019-Holtec 2002, all). DOE used a 20-year storage period to estimate impacts for canister storage under the assumptions that the average spent nuclear fuel age would be 25 years and that the spent nuclear fuel would be in a spent nuclear fuel storage pool for 5 years before being moved to dry storage. DOE based the impacts of the storage of high-level radioactive waste were the impacts in *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage,*

Table 8-9. Cumulative radiological impacts of storage and loading at the generator sites for workers.

Action	Radiation dose (person-rem)	Latent cancer fatalities
Loading of canisters	120	0.074
Storage of canisters[a]	2,400	1.5
Storage of high-level radioactive waste[b]	14,000	8.5
Storage of DOE spent nuclear fuel[c]	3,600	2.2
Proposed Action	10,000	6.0
Total	30,000	18

a. DIRS 175019-Holtec 2002, all.
b. DIRS 101816-DOE 1997, all.
c. DIRS 101802-DOE 1995, all.

and Disposal of Radioactive and Hazardous Waste (DIRS 101816-DOE 1997, all). The Department based impacts of the storage of DOE spent nuclear fuel on the impacts in *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DIRS 101802-DOE 1995, all). There would be an estimated 18 latent cancer fatalities in the exposed population of workers for loading and storage at the generator sites. These activities would take place at 76 facilities across the United States over 50 years, so the probability of a latent cancer fatality for an individual worker at an individual facility would be small.

Table 8-10 lists the cumulative industrial safety impacts of the loading and storage of spent nuclear fuel and high-level radioactive waste at the generator sites. DOE based the estimation of industrial safety impacts on the same methods and data as those for the loading of TAD canisters (Appendix G). DOE based the impacts of canister storage at the commercial generator sites on data from Holtec (DIRS 175019-Holtec 2002, all) for surveillance and maintenance of dry storage casks.

Table 8-10. Cumulative industrial safety impacts of storage and loading at the generator sites for workers.

Action	Industrial safety fatalities
Loading and storage of canisters[a]	0.0079
Storage of high-level radioactive waste[b]	2.5
Storage of DOE spent nuclear fuel[c]	<1
Proposed Action	0.25
Total	<3.8

a. DIRS 175019-Holtec 2002, all.
b. DIRS 101816-DOE 1997, all.
c. DIRS 101802-DOE 1995, all.

DOE based the estimates of impacts of canister storage on a 20-year storage time. It based the impacts of storage of high-level radioactive waste on the impacts in *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DIRS 101816-DOE 1997, all). The Department based the impacts of DOE spent nuclear fuel storage on the impacts in *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DIRS 101802-DOE 1995, all). There would be an estimated 4 fatalities from industrial accidents in the population of workers for loading and storage at the generator sites. These activities would take place at 76 facilities across the United States over 50 years, so the probability of a fatality for an individual worker at an individual facility would be small.

8.4.1.2 Inventory Module 1 or 2 Impacts at Generator Sites

This section describes the potential cumulative impacts of loading operations at the generator sites for Inventory Module 1 and 2. Chapter 6 presents the cumulative impact results of transportation for the Proposed Action inventory. Appendix G contains detailed analysis results.

For the Proposed Action, DOE would ship 70,000 MTHM of spent nuclear fuel and high-level radioactive waste from the generator sites to the repository. For Module 1, the inventory would be about 143,300 MTHM. Module 2 includes the Module 1 inventory and 2,203 canisters of Greater-Than-Class C radioactive waste. Table 8-11 lists the numbers of rail and truck casks for the Proposed Action and each of the Modules.

Table 8-11. Numbers of rail and truck casks for the Proposed Action, Module 1, and Module 2.

Mode	Proposed Action	Module 1	Module 2
Rail	9,495	21,909	24,112
Truck	2,650	5,025	5,025
Total	12,145	26,934	29,137

In Section 6.2.1, DOE estimated 1.4 fatalities from exposure to vehicle emissions and from traffic fatalities for shipment of empty TAD canisters and campaign kits to generator sites. Based on the increase in the number of casks for Module 1—about 120 percent—DOE estimated there could be about 3 fatalities from shipment of TAD canisters and campaign kits to generator sites for Module 1. For Module 2, the increase in the number of casks would be about 140 percent, and DOE estimated there could also be about 3 fatalities from shipment of TAD canisters and campaign kits to generator sites. Table 8-12 summarizes these impacts.

Table 8-12. Summary of cumulative fatality impacts at generator sites.

Activity	Proposed Action	Module 1	Module 2
Transportation of canisters to generator sites	1.4[a]	3.1[a]	3.4[a]
Radiation exposure of public around generator sites	0.0017	0.0038	0.0041
Radiation exposure of workers at generator sites	6	13	14
Industrial accidents at generator sites	0.41[b]	0.91[b]	0.98[b]

a. From exposure to vehicle emissions and from traffic fatalities.
b. From industrial accidents, exposure to vehicle emissions, and traffic fatalities for involved and noninvolved workers.

In Section 6.2.2, DOE estimated the probability of a latent cancer fatality for members of the public who would be exposed to radioactive releases from the generator sites would be 0.0017. Based on the increase in the number of casks for Modules 1 and 2, DOE estimated the probability of a latent cancer fatality for the exposed members of the public would be 0.0038 for Module 1 and 0.0041 for Module 2 (Table 8-12).

In Section 6.2.3, DOE estimated there would be 6 latent cancer fatalities in the population of workers who were exposed to radiation from loading activities at the generator sites. Based on the increase in the number of casks shipped for Modules 1 and 2, DOE estimated there could be 13 latent cancer fatalities among workers for Module 1 and 14 latent cancer fatalities for Module 2 (Table 8-12).

In Section 6.2.4, DOE estimated 0.41 fatality from industrial accidents, exposure to vehicle emissions, and traffic fatalities for involved and noninvolved workers at the generator sites. Based on the increase in the number of casks shipped for Modules 1 and 2, DOE estimated 0.91 fatality for Module 1 and 0.98 fatality for Module 2 (Table 8-12).

In Section 6.2.5, DOE estimated the probability of a latent cancer fatality for the population within 16 kilometers (10 miles) of a generator site would range from 1.5×10^{-12} (1 chance in 700 billion) for an accident that involved the drop of a spent nuclear fuel assembly to 3.6×10^{-4} (1 chance in 3,000) for an accident that involved the drop of a transfer cask. Although the probability of these accidents could increase with the handling of more spent nuclear fuel, the consequences of the accidents would not increase and the impacts of loading accidents under Module 1 or 2 would be the same as those for the Proposed Action.

8.4.1.3 Inventory Module 1 and 2 Impacts for National Transportation

Table 8-13 lists the impacts for national transportation of spent nuclear fuel and high-level radioactive waste by rail and some truck shipments for the Proposed Action, Module 1, and Module 2. As with the cumulative impacts of loading and storage at the generator sites, DOE based the impacts of Module 1 and Module 2 on the impacts of the Proposed Action and on the increases in the number of rail and truck casks for Modules 1 and 2. For the Proposed Action, DOE estimated there could be a total of about 8 fatalities. The majority of these fatalities (about 80 percent) would be from worker radiation exposures and traffic accidents. The Department estimated there could be about 18 total fatalities for Module 1 and about 19 total fatalities for Module 2. As with the Proposed Action, the majority of these fatalities would be from worker radiation exposures and traffic fatalities.

DOE does not expect radiological impacts for maximally exposed workers and members of the public to change from the Proposed Action due to the conservative assumptions for the analysis of the Proposed Action (Chapter 6, Section 6.3). Maximally exposed workers would include a crew member, an inspector, and a rail yard crew member; maximally exposed members of the public would be a resident along a route, a person in a traffic jam, a person at a service station, and a resident near a rail stop). The assumptions for estimation of radiological doses include the use of the maximum allowed dose rate and conservative estimates of exposure distance and time. For example, DOE used the U.S. Department of Transportation maximum allowable dose rate of 10 millirem per hour at a distance of 2 meters (6.6 feet) [40 CFR 173.44(b)] to estimate exposures to individuals. In addition, it would be unlikely that the actual exposure distance and time for workers and the public would be higher than DOE's conservative assumptions for the Proposed Action are unlikely to be exceeded for Inventory Module 1 or 2.

8.4.1.4 Inventory Module 1 and 2 Impacts for Transportation Impacts Associated with the Repository

Chapter 6, Section 6.4.2 describes the impacts of the transportation of construction materials, repository components, and consumables to the repository; the impacts from workers who would commute to the repository; and the impacts of offsite shipment of nonhazardous solid waste and hazardous, mixed, and low-level radioactive waste. DOE estimated about 13 fatalities from exposure to vehicle emissions and 44 to 46 traffic fatalities due to these transportation activities.

The implementation of Inventory Module 1 or 2 would increase this transportation as a result of additional subsurface development and the longer time necessary for repository development, emplacement, and closure. For example, for Module 1 and Module 2, DOE would need additional

Table 8-13. National transportation impacts for the Proposed Action, Module 1, and Module 2.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Proposed Action										
Caliente										
Rail	9,495	800	4,700	0.48	2.8	0.99	4.1	0.0025	2.1	6.4
Truck	2,650	350	880	0.21	0.53	0.13	0.068	0.00041	0.57	1.4
Total	12,145	1,200	5,600	0.69	3.4	1.1	4.2	0.0025	2.7	7.8
Mina										
Rail	9,495	700	5,100	0.42	3	0.88	3.7	0.0022	2.2	6.5
Truck	2,650	350	880	0.21	0.53	0.13	0.068	0.00041	0.57	1.4
Total	12,145	1,100	5,900	0.63	3.6	1	3.7	0.0022	2.8	8
Module 1										
Caliente										
Rail	21,909	1,900	11,000	1.1	6.6	2.3	9.5	0.0057	4.8	15
Truck	5,025	660	1,700	0.4	1	0.25	0.13	0.00077	1.1	2.7
Total	26,934	2,500	13,000	1.5	7.6	2.5	9.6	0.0058	5.9	18
Mina										
Rail	21,909	1,600	12,000	0.98	7	2	8.5	0.0051	5	15
Truck	5,025	660	1,700	0.4	1	0.25	0.13	0.00077	1.1	2.7
Total	26,934	2,300	13,000	1.4	8	2.3	8.6	0.0052	6.1	18
Module 2										
Caliente										
Rail	24,112	2,000	12,000	1.2	7.2	2.5	10	0.0062	5.3	16
Truck	5,025	660	1,700	0.4	1	0.25	0.13	0.00077	1.1	2.7
Total	29,137	2,700	14,000	1.6	8.2	2.8	11	0.0063	6.4	19
Mina										
Rail	24,112	1,800	13,000	1.1	7.7	2.2	9.3	0.0056	5.5	17
Truck	5,025	660	1,700	0.4	1	0.25	0.13	0.00077	1.1	2.7
Total	29,137	2,400	15,000	1.5	8.7	2.5	9.5	0.0057	6.6	19

Note: Totals might differ from sums due to rounding.

repository components such as waste packages and drip shields. With the increased transportation of other material, personnel, and repository-generated wastes for Module 1 or 2, these transportation impacts could increase to about 14 fatalities from exposure to vehicle emissions and 47 to 50 traffic fatalities.

8.4.1.5 Cumulative Impacts from the Proposed Action, Inventory Module 1 or 2, and Other Federal, Non-Federal, and Private Actions

The overall assessment of the cumulative national transportation impacts for past, present, and reasonably foreseeable future actions concentrated on the cumulative impacts of offsite transportation, which would yield potential radiation doses to a greater portion of the general population than onsite transportation and could result in fatalities from traffic accidents. DOE used the collective dose to workers and to the general population to quantify overall cumulative radiological transportation impacts. The Department chose this measure because it relates directly to latent cancer fatalities with the use of a cancer risk coefficient and because of the difficulty in identification of a maximally exposed individual for shipments throughout the United States from 1943 through 2073. Operations at the Hanford Site and the Oak Ridge Reservation began in 1943, and 2073 is when the Repository SEIS analysis assumed that radioactive material shipments to the repository for Inventory Module 1 or 2 would end.

The cumulative impacts of the transportation of radioactive material would consist of impacts from:

- Historic DOE shipments of radioactive material to and from the Nevada Test Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, the Hanford Site, the Oak Ridge Reservation, and naval spent nuclear fuel and test specimens.

- Reasonably foreseeable actions that include the transportation of radioactive material in various DOE NEPA analyses; for example, the Nevada Test Site EIS (DIRS 101811-DOE 1996, all), the DOE spent nuclear fuel management EIS (DIRS 101802-DOE 1995, all; DIRS 101812-DOE 1996, all), and the DOE waste management EIS (DIRS 101816-DOE 1997, all) (see Table 8-14). In some cases, transportation impacts included impacts that might have been counted twice. For example, Table 8-14 includes the impacts from shipment of 40,000 MTHM of spent nuclear fuel to a potential Private Fuel Storage Facility in Tooele County, Utah (DIRS 157761-NRC 2001, all), but the impacts from the Proposed Action do not account for this 40,000 MTHM. Table 8-14 includes reasonably foreseeable projects that include limited transportation of radioactive material (for example, shipment of submarine reactor compartments from the Puget Sound Naval Shipyard to the Hanford Site for burial and shipments of uranium billets and low specific activity nitric acid from the Hanford Site to the United Kingdom). In addition, for reasonably foreseeable future actions for which there was no identified preferred alternative or Record of Decision, the analysis used the alternative that would result in the largest impacts. While this is not an exhaustive list of the projects that could include limited transportation of radioactive material, it indicates that the impacts of such projects would be low in comparison to major projects or general transportation.

- General radioactive materials transportation that would not relate to a particular action; for example, shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities.

Table 8-14. Cumulative transportation-related health effects.

Category	Worker dose (person-rem)	General population dose (person-rem)	Traffic fatalities
Historical DOE shipments (DIRS 101811-DOE 1996, all)	330	230	NL
Reasonably foreseeable actions			
Private Fuel Storage Facility (DIRS 157761-NRC 2001, all)	24	184	0.78
Sodium-Bonded Spent Nuclear Fuel (DIRS 157167-DOE 2000, all)	0.0044	0.032	0.0001
Idaho High-Level Waste and Facilities (DIRS 179508-DOE 2002 , all)	520	2,900	0.98
Surplus Plutonium Disposition (DIRS 118979-DOE 1999, all)	60	67	0.053
Sandia National Laboratories Site-Wide EIS (DIRS 157155-DOE 1999, all)	94	590	1.3
Depleted Uranium Hexafluoride (DIRS 152493-DOE 1999, all)	--	750	4
Tritium Production in a Commercial Light Water Reactor (DIRS 157166-DOE 1999, all)	16	80	0.06
Parallex Project (DIRS 157153-DOE 1999, all)	0.00001	0.00007	0.00005
Los Alamos National Laboratory Site-Wide EIS (DIRS 157154-DOE 1999, all)	580	310	8
Plutonium Residues at Rocky Flats (DIRS 155932-DOE 1998, all)	2.1	1.3	0.0078
Import of Russian Plutonium-238 (DIRS 157156-DOE 1993, all)	1.8	4.4	0.0036
Nevada Test Site Expanded Use (DIRS 101811-DOE 1996, all)	--	150	8
Spent nuclear fuel management (DIRS 101802-DOE 1995, all; DIRS 101812- DOE 1996, all)	360	810	0.77
Waste Management PEIS (DIRS 101816-DOE 1997, all)	16,000	20,000	36
Waste Isolation Pilot Plant (DIRS 148724-DOE 1997, Appendix E)	790	5,900	5
Molybdenum-99 production (DIRS 101813-DOE 1996, all)	240	520	0.1
Tritium supply and recycling (DIRS 103208-DOE 1995, all)	--	--	0.029
Surplus HEU disposition (DIRS 103216-DOE 1996, all)	400	520	1.1
Storage and Disposition of Fissile Materials (DIRS 103215-DOE 1996, all)	--	2,400	5.5
Stockpile Stewardship (DIRS 103217-DOE 1996, all)	--	38	0.064
Pantex (DIRS 103218-DOE 1996, all)	250	490	0.006
West Valley (DIRS 179454-DOE 2003, all)	520	410	0.15
S3G and D1G prototype reactor plant disposal (DIRS 103221-DOE 1997, all)	2.9	2.2	0.010
S1C prototype reactor plant disposal (DIRS 103219-DOE 1996, all)	6.7	1.9	0.0037
Container system for Naval spent nuclear fuel (DIRS 101941-USN 1996, all)	11	15	0.045
Cruiser and submarine reactor plant disposal (DIRS 103479-USN 1996, all)	5.8	5.8	0.00095
Submarine reactor compartment disposal (DIRS 103477-USN 1984, all)	--	0.053	NL
Uranium billets (DIRS 103189-DOE 1992, all)	0.5	0.014	0.00056
Nitric acid (DIRS 103212-DOE 1995, all)	0.43	3.1	NL
Los Alamos Relocation of Area 18 FEIS (DIRS 162639-DOE 2002, all)	< 1	< 1	0.00020
Construction, Operation of Depleted DUF6 Conversion Facility, Portsmouth, Ohio FEIS (DIRS 182373-DOE 2004, all)	520	29	0.45
Enrichment Facility in Lea County, New Mexico (DIRS 182375-NRC 2005, all)	10	170	0.6
Decontamination, Demolition, and Removal of Facilities at West Valley (DIRS 182374-DOE 2006, all)	14	11	0.013
Hanford Site Solid Waste Program FEIS (DIRS 182376-DOE 2004, all)	1,200	11,000	2.4
Moab Uranium Mill Tailings FEIS (DIRS 182377-DOE 2005, all)	0.09	3.4	0.33
MOX Fuel Fabrication at Savannah River Site (DIRS 178816-NRC 2005, all)	530	560	0.056
GNEP	In preparation	In preparation	In preparation
Complex Transformation PEIS	In preparation	In preparation	In preparation
General radioactive material transportation			
1943 to 2073	350,000	300,000	28
Subtotal of non-repository-related transportation impacts	370,000	350,000	100
1943 to 2073			
Proposed Action	5,600–5,900	1,100–1,200	2.7–2.8
Module 1	13,000	2,300–2,500	5.9–6.1
Module 2	14,000–15,000	2,400–2,700	6.4–6.6
Total collective dose (total latent cancer fatalities) and total traffic fatalities			
Proposed Action	380,000 (230)	350,000 (210)	100
Module 1	380,000 (230)	350,000 (210)	110
Module 2	390,000 (230)	350,000 (210)	110

NL = Not listed; information was not listed in the reference.

- Shipments of spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste under the Proposed Action or Inventory Module 1 or 2.

NRC evaluated these types of shipments based on a survey of radioactive materials transportation published in 1975 (DIRS 101892-NRC 1977, all). Categories of radioactive material evaluated in this NRC document included: (1) limited quantity shipments, (2) medical, (3) industrial, (4) fuel cycle, and (5) waste. NRC estimated that the annual collective worker dose for these shipments was 5,600 person-rem (DIRS 101892-NRC 1977, p. 4-15). The annual collective general population dose for these shipments was estimated to be 4,200 person-rem (DIRS 101892-NRC 1977, p. 5-52). These collective dose estimates were used to estimate transportation collective doses for 1943 through 1982 (40 years). Based on the NRC transportation dose assessments, the cumulative transportation collective doses for 1943 through 1982 were 220,000 person-rem for workers and 170,000 person-rem for the general population.

In 1983, another survey of radioactive materials transportation in the United States was conducted. This survey included NRC, Agreement State licensees, and DOE. Both spent nuclear fuel and radioactive waste shipments were included in the survey. Weiner et al. (DIRS 146270-1991, all) used the survey to estimate collective doses from general transportation. These transportation dose assessments were used to estimate transportation doses for 1983 through 2073 (91 years). Weiner et al. evaluated eight categories of radioactive material shipments: (1) industrial, (2) radiography, (3) medical, (4) fuel cycle, (5) research and development, (6) unknown, (7) waste, and (8) other. Based on a median external exposure rate, an annual collective worker dose of 1,400 person-rem and an annual collective general population dose of 1,400 person-rem were estimated (DIRS 146270-Weiner et al. 1991, Table VI). Over the 91-year period from 1983 through 2073, the collective worker and general population doses would be 130,000 person-rem.

For the period 1943 through 2073, the collective worker dose would be 350,000 person-rem and the collective population dose would be 300,000 person-rem.

NRC evaluated traffic fatalities and estimated that there could be 0.213 traffic fatality per year from radioactive material shipments (DIRS 101892-NRC 1977, p. 5-52). Using this estimate, for the 131-year period between 1943 through 2073, there could be 28 traffic fatalities.

Table 8-14 lists the cumulative doses to workers and the general population from the transportation of radioactive material, and it lists the numbers of traffic fatalities. The estimated cumulative transportation-related collective worker doses would range from 380,000 to 390,000 person-rem (230 latent cancer fatalities) for the Proposed Action, Module 1, and Module 2. The estimated general population doses would be about 350,000 person-rem (210 latent cancer fatalities) for the Proposed Action, Module 1, and Module 2. Most of the doses to workers and the general population would result from general transportation of radioactive material. For perspective, about 600,000 people die from cancer in the United States every year.

For transportation accidents that involved radioactive material, the dominant risk would be from accidents that do not relate to the cargo (traffic or vehicular accidents). The radiological accident risk (latent cancer fatalities) from transportation accidents is typically less than 1 percent of the vehicular accident risk. In addition, no acute radiological fatalities from transportation accidents have ever occurred in the United

States. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

From 1943 through 2073, DOE estimated 5 million motor vehicle fatalities and about 130,000 railroad accident fatalities. Based on the estimated number of traffic fatalities for the reasonably foreseeable actions and for the Proposed Action and Inventory Module 1 or 2 in Table 8-14, the transport of radioactive material could contribute a total of about 100 to 110 fatalities.

8.4.2 NEVADA RAIL ALIGNMENT TRANSPORTATION

This section summarizes cumulative impacts for Nevada rail transportation from Chapter 5 of the Rail Alignment EIS. DOE evaluated two rail alignments—Caliente and Mina. The area for each rail alignment would be from the node of the alignment to the proposed repository. The following sections discuss the impacts to each rail alignment by resource area.

8.4.2.1 Physical Setting

The Rail Alignment EIS cumulative impact section evaluates two areas of physical setting impacts: disturbance of physical resources and known or potentially contaminated soils. Activities that would change the physical setting include cuts and fills and new structures such as buildings and bridges. Given the large amount of land potentially available for development of existing and reasonably foreseeable projects, and the small percentage of potentially available land required for the proposed railroad, overall cumulative impacts to physical setting in the Caliente or Mina rail alignment region of influence would be small.

The major sources of existing soil contamination in the Caliente rail alignment region of influence include mining and the Nevada Test Site. These two sources, along with the Hawthorne Army Depot, are the major sources of existing soil contamination in the Mina rail alignment region of influence. Mining wastes still remain from older operations before the regulatory framework required waste management and cleanup. Historical contamination of soil resources at the Nevada Test Site resulted primarily from radioactive-waste management sites and nuclear testing activities. Explosives and heavy metals are the primary soil contamination concerns at the Hawthorne Army Depot. The proposed railroad could result in very localized contamination of soils through occasional spills (such as fuel, oil, and solvents). However, such incidents would be minor in scope and quickly mitigated in accordance with plans and regulations. All existing and foreseeable projects would be subject to the same regulations. Cumulative impacts related to contamination of soils in Caliente or Mina rail alignment would be small.

8.4.2.2 Land Use and Ownership

The Rail Alignment EIS cumulative impact section evaluates several areas of land use and ownership impacts: land use changes, existing or potential land use conflicts, energy and mineral development, Bureau of Land Management land sales and other disposals, recreational land use, Bureau of Land Management rights of way, other Bureau land management actions, and urbanization and economic development initiatives for the Caliente and Mina rail alignments.

Land use changes. Many of the past, present, and reasonably foreseeable future actions in the Caliente and Mina rail alignment regions of influence result in land use changes. The Caliente rail alignment would disturb up to 165 square kilometers (40,000 acres) of Bureau of Land Management land, which is approximately 0.3 percent of the Bureau-administered land in Lincoln, Nye, and Esmeralda counties. The Mina rail alignment would disturb up to 110 square kilometers (27,300 acres) of land, which would directly affect about 0.25 percent of Bureau-administered land in Lyon, Mineral, Esmeralda, and Nye counties. Other existing and reasonably foreseeable major land uses in the Caliente or Mina rail alignment region of influence include:

- Yucca Mountain Repository—about 8 square kilometers (2,000 acres),
- Nevada Test and Training Range—about 12,000 square kilometers (3 million acres),
- Nevada Test Site—about 3,200 square kilometers (800,000 acres),
- Coyote Springs Development Project—about 170 square kilometers (43,000 acres),
- *Lincoln County Land Act of 2000*—53 square kilometers (13,000 acres),
- *Lincoln County Conservation, Recreation, and Development Act of 2004*—about 360 square kilometers (90,000 acres),
- Naval Air Station Fallon and Range Training complex—about 980 square kilometers (242,000 acres),
- Walker River Paiute Reservation—about 1,309 square kilometers (323,400 acres),
- Hawthorne Army Depot—about 600 square kilometers (147,000 acres), and
- Reno and Carson City Expansion—about 25 square kilometers (6,300 acres).

Considering both the proposed railroad and existing and reasonably foreseeable land uses and land ownership, cumulative impacts from land use changes for the Caliente or Mina rail alignment would be small.

Existing or potential land use conflicts. The construction and operation of a rail line in the Caliente or Mina rail alignment would have potential direct and indirect conflicts with grazing uses, access to grazing infrastructure, access to mineral resources, recreational resources, other linear rights-of-way (for example, utility corridors), and wildlife movement patterns in some locations. Even with the existing and reasonably foreseeable land use changes, the region as a whole would continue its traditional ways, with grazing and wildlife habitat as major land uses, and cumulative impacts related to land use conflicts in the Caliente or Mina rail alignment would be small.

Energy and mineral development. Within the Caliente and Mina rail alignment regions of influence, most mining and energy development activities would occur on federal lands. Any potential conflict of the proposed railroad with energy and mineral development would be small in scope and would occur in localized areas. The Bureau of Land Management will have a major role in mitigating and monitoring potential effects through its mining and reclamation requirements, NEPA, and other elements of the regulatory framework. All existing and foreseeable projects would be subject to regulatory requirements and Bureau policies and plans related to energy and mineral development. Therefore, cumulative impacts resulting in land use conflicts related to energy and mineral development along the Caliente or Mina rail alignment would be small.

Bureau of Land Management land sales and other disposals. The Bureau of Land Management has designated a number of land parcels in the Caliente rail alignment region of influence and plans to designate parcels in the Mina rail alignment region of influence, which could result in permanent land changes that could cause increasing urbanization and economic development. While the proposed railroad would operate within the regional context of Bureau land disposal efforts and any related implication and effects, it would have no affect on, nor be affected by, Bureau land disposal efforts.

Recreational land use. Public lands in the Caliente and Mina rail alignment regions of influence provide a number of diverse recreation opportunities. The Bureau of Land Management has designated certain lands as recreation management areas. As growth and development occur in the Caliente and Mina cumulative impacts regions of influence, the potential for conflict with recreational resources also will increase. In the Caliente rail alignment region of influence, the *Lincoln County Conservation, Recreation, and Development Act of 2004* (Public Law 108-424) designated the Silver State Off-Highway Vehicle Trail, which intersects the Caliente rail alignment in three places. These intersections can be managed effectively by DOE and the Bureau of Land Management. For the Mina rail alignment, DOE has sighted the rail alignment to avoid wilderness areas and other major recreational resources to the maximum extent practicable. Cumulative impacts to access to and use of recreational resources along the Caliente or Mina rail alignment would be small.

Bureau of Land Management rights-of-way. Utility and other right-of-way crossings are common to linear projects such as roads, railroads, and pipelines. Land areas for the Caliente rail alignment, construction camps, quarries, and access roads would cross or overlap as many as 34 existing or proposed utility rights-of-way. Land areas for the Mina rail alignment, construction camps, quarries, and access roads would cross or overlap existing or proposed utility rights-of-way in approximately 22 to 29 locations. The crossings would have small impacts because standard engineering procedures and appropriate design details would be used. Cumulative impacts to Bureau right-of-way holders in the Caliente or Mina rail alignment region of influence would be small.

Other Bureau of Land Management land management actions. The Caliente rail alignment would cross several Bureau of Land Management planning areas that are covered by the Las Vegas and Tonopah Resource Management Plans and the Schell and Caliente Management Framework Plans. The Mina rail alignment would cross three Bureau of Land Management areas including Las Vegas, Battle Mountain, and Carson City, which are covered by several management plans. Bureau of Land Management land management efforts will play a major role in balancing among multiple uses chosen for public lands. The proposed railroad's contribution to cumulative impacts to Bureau land-management planning and actions in the Caliente or Mina rail alignment region of influence would be small.

Urbanization and economic development initiatives. The Caliente and Mina rail alignment regions of influence have seen increased urbanization and economic development and have generally planned for and solicited ways to grow. The concepts for growth include industrial park development, increased retail opportunities, and increased housing. With or without the proposed railroad, urbanization and economic development activities, while increasing, would not substantially change the overall undeveloped character of the Caliente or Mina rail alignment region of influence.

8.4.2.3 Aesthetic Resources

Cumulative impacts to aesthetic resources from the Caliente or Mina rail alignment and other regional activities would primarily result from modifications to natural viewsheds. The Bureau of Land Management Visual Resource Management System has been applied to determine impacts from the proposed rail alignments to these viewsheds. There are no known interactions of the Caliente or Mina rail alignment with other reasonably foreseeable activities that would affect a Class I or Class II viewshed.

8.4.2.4 Air Quality and Climate

The air quality impact analysis for the Caliente and Mina rail alignments assessed potential impacts through several means including air quality modeling of maximum concentrations relevant to National Ambient Air Quality Standards. The analysis concluded that emissions during construction or operation of the rail line or any associated facilities would generally be in conformance with applicable standards for both rail alignments with some exceptions. For Caliente, the possible exception is the 24-hour National Ambient Air Quality Standards for PM_{10}, which could be exceeded from quarry operations at South Reveille Valley during the construction phase. For Mina, the possible exception is the 24-hour standard for both PM_{10} and $PM_{2.5}$ near the construction right-of-way at Mina and Schurz during the relatively short construction period, and at the Staging Yard at Hawthorne and the potential Garfield Hills quarry. Potential cumulative impacts to air quality and climate from construction and operation of the proposed railroad along the Caliente or Mina rail alignment would be small, but could approach moderate if the potential exceedence of the National Ambient Air Quality Standards noted above occurred.

8.4.2.5 Surface-Water Resources

The Rail Alignment EIS cumulative impact section evaluates two areas of surface-water resources impacts: changes in drainage, infiltration rates, and flood control, and spill and contamination potential.

Changes in drainage, infiltration rates, and flood control. Potential cumulative impacts due to changes in drainage, infiltration rates, and flood control would be very small and localized. An area of drainage and flooding concern in the Caliente rail alignment is the Meadow Valley Wash area near the City of Caliente. The area has a history of flooding affecting roads, trails, and rail lines, and multiple agencies are conducting an evaluation of the area to identify appropriate measures to reduce direct, indirect, or cumulative impacts.

Spill and contamination potential. While the risk of spill and associated water contamination for the Caliente or Mina rail alignments cannot be totally eliminated, risks would be managed through regulatory controls so the resulting cumulative impacts would be small.

8.4.2.6 Groundwater Resources

Caliente Rail Alignment
Representative existing and reasonably foreseeable water users in the Caliente rail alignment region of influence include:

- Agricultural use consumes the most water in the Caliente rail alignment region of influence;
- The Toquop power plant FEIS (DIRS 174208-BLM 2003, all);

- The Clark, Lincoln, and White Pine Groundwater Development Project (Southern Nevada Water Authority) (DIRS 175909-Hafen et al. 2003, all);

- The combined effects of the Lincoln County Land Act Groundwater Development Project and the Kane Springs Valley Groundwater Development Project (DIRS 175909-Hafen et al. 2003, all);

- Proposed new municipal or irrigation wells in hydrographic areas 181, 208, and 172;

- The recently constructed or planned power plants (water-cooled) in the Apex and Moapa areas;

- The Nevada Test Site;

- Grazing activity in the 38 allotments around the proposed Caliente rail alignment; and

- The Yucca Mountain Repository.

Excluding the large agricultural water use in the Caliente rail alignment region of influence, cumulative water use for the projects described above could total more than 430 million cubic meters (350,000 acre-feet) per year. Overall, the share of water that would be committed to construction and operation of the proposed railroad would represent a small portion of water use in the Caliente rail alignment region of influence, which would still be dominated by agriculture. Committed groundwater resources already exceed annual perennial yield values (a measure of available groundwater supply replenished each year through recharge) in some of the groundwater basins (hydrographic areas) that would be affected by the proposed railroad. Based on the proposed locations of new wells in specific hydrographic areas along the Caliente rail alignment, additional groundwater appropriations would be needed in 19 hydrographic areas. However, committed (cumulative) groundwater resources currently exceed estimated perennial yields in eight of these hydrographic areas. Overall, the needs of the proposed railroad would represent a small portion of the current cumulative water usage in the Caliente rail alignment region of influence, which in some locations would continue to exceed perennial yield values. Overall, the needs of the proposed railroad would represent a small portion of the current cumulative water use in the Caliente rail alignment region of influence, which in some locations would continue to exceed perennial yield values.

Mina Rail Alignment

Representative existing and reasonably foreseeable water users in the Mina rail alignment region of influence include:

- Public-supply/municipal, agricultural (stock watering), and mining;
- The Nevada Test Site; and
- The Yucca Mountain Repository.

The proposed Mina rail alignment would use up to about 7.34 million cubic meters (5,950 acre-feet) of water during the construction phase, with about 80 percent of that water use occurring in the first 2 years of construction. About 23,000 cubic meters (17 acre-feet) of water would be needed annually during Mina rail alignment operations.

Committed groundwater resources in the Mina rail alignment region of influence already exceed annual perennial yield values (a measure of available groundwater supply replenished each year through recharge) within some of the groundwater basins (hydrographic areas) that would be affected by the proposed railroad. Based on the proposed locations of new wells in specific hydrographic areas along the Mina rail alignment, additional groundwater appropriations would be needed in 19 hydrographic areas. However, committed (cumulative) groundwater resources currently exceed estimated perennial yields in eight of these hydrographic areas. Overall, the needs of the proposed railroad would represent a small portion of current cumulative water use in the Mina rail alignment region of influence, which in some locations would continue to exceed perennial yield values. Overall, the needs of the proposed railroad would represent a small portion of the current cumulative water use in the Mina rail alignment region of influence, which in some locations would continue to exceed perennial yield values.

8.4.2.7 Biological Resources

The Rail Alignment EIS cumulative impact section evaluates several areas of biological resources impacts: habitat loss and fragmentation, invasive species and noxious weeds, special-status species, and wildfires.

Habitat loss and fragmentation. Impacts to the Caliente rail alignment would be from existing activities such as the Nevada Test and Training Range and Nevada Test Site and proposed rights-of-way and the Coyote Springs development. Impacts to the Mina rail alignment would be from existing activities such as the Nevada Test and Training Range, the Nevada Test Site, Naval Air Station Fallon, and the Hawthorne Army Depot and proposed industrial parks and planned communities. These activities have resulted or will result in cumulative land disturbance. In areas proposed for railroad operational purposes, the impacts to vegetation would typically be moderate in scope, and would cumulatively add to habitat loss and fragmentation. However, in areas slated for short-term use during construction, such as construction camps, revegetation and reclamation efforts would result in replacement of topsoil, reseeding of native species, monitoring for success, and eventual return of a native vegetation community somewhat comparable to predisturbance conditions. Cumulative impacts due to habitat loss and fragmentation in the Caliente or Mina rail alignment regions of influence would range from small to moderate through the construction and operations phases.

Invasive species and noxious weeds. Linear disturbances such as pipelines, roads, utility corridors, or rail alignments that cross relatively undisturbed land have the potential to exacerbate the spread of invasive species and noxious weeds into areas not previously affected. As the invasive or noxious weeds become established along the linear features they spread to adjacent areas, affecting the plant and animal communities beyond the actual disturbance, and are able to out-compete native species by responding more rapidly to the infrequent availability of water. These impacts could occur as a result of construction and operation of the rail alignments; however, strict adherence to best management practices should reduce the potential for impacts. Cumulative impacts due to the introduction and spread of invasive species and noxious weeds in the Caliente or Mina rail alignment regions of influence would be small.

Special-status species. Multi-species Habitat Conservation Plans are underway in two places in the Caliente rail alignment region of influence: (1) the Coyote Springs area and (2) in southern Lincoln County in the area of the recent Bureau of Land Management land disposal. In addition, there is a single-species (desert tortoise) Habitat Conservation Plan being developed in the Pahrump area of Nye County. These plans would support development of private lands while accounting for the potentially affected species. No major effects on special-status species would result from construction and operation of the proposed railroad along the Caliente or Mina rail alignments. DOE would conduct any required consultation with the U.S. Fish and Wildlife Service in accordance with the Endangered Species Act (16 U.S.C. 1531 et seq.). There is a substantial regulatory framework, to which all projects are subject, that serves to evaluate and protect special-status species; therefore, cumulative impacts to special-status species would be small.

Wildfires. Sources of regional wildfires are both natural (for example, lightning) and human-caused. With increased activity in the Caliente rail alignment region of influence, the potential for future human-caused fires increases. Because the Bureau of Land Management administers most of the land in the Caliente rail alignment region of influence, it has primary fire-avoidance and firefighting responsibilities. Both the proposed railroad project and other reasonably foreseeable future actions would likely implement appropriate fire-avoidance strategies in consultation with the Bureau. Potential cumulative impacts from wildfires would be small.

8.4.2.8 Noise and Vibration

The Rail Alignment EIS cumulative impact section evaluates several areas of noise and vibration impacts: railroad noise, urban noise, aircraft noise, and vibration.

Railroad Noise

The Caliente rail alignment has several sources of railroad noise, including: the sounds associated with the Union Pacific Railroad in and near the City of Caliente include wayside noise (noise generated by the cars and locomotives) and horn sounding. The Toquop Energy Project could involve a new short rail spur of about 50 kilometers (30 miles) in an isolated part of Lincoln County south of Caliente. This spur would connect with the Union Pacific railroad system but would be in an area that would not have any identifiable noise receptors. The potential noise impacts of the Caliente rail alignment (as evaluated through noise modeling near Caliente, in Garden Valley, and in Goldfield) would be small. Construction and operation of a railroad along the Caliente rail alignment would introduce railroad noise into areas of the Caliente rail alignment region of influence that previously had none. This could result in annoyance for some people.

In the Mina rail alignment cumulative impact region of influence, there is an existing branch line extending from Hazen, Nevada, to the Hawthorne Army Depot. The noise associated with railroad operations is part of the existing environment, specifically in the Schurz area where the railroad's presence is very evident. Hawthorne Army Depot is planning to construct a rail siding, known as the Wabuska Spur, which would increase its rail capacity. Potential impacts from noise along the Mina rail alignment would be expected to be small. However, the proposed railroad would introduce or expand noise sources into areas of the Mina rail alignment region of influence that previously had very limited railroad noise. This could result in incremental annoyance effects for some people. However, the existing rail line through Schurz would be eliminated, which would provide a substantial reduction in annoyance effects for people in Schurz.

Urban Noise

At present, urban noise in the Mina rail alignment region of influence is limited because there are only a few cities and communities. However, with economic development and growth goals throughout the Caliente and Mina rail alignment regions of influence, the number and scope of urbanized areas is expected to increase. The proposed railroad would have a very small effect on urbanization in the area, and its effect on urban noise in the Caliente or Mina rail alignment region of influence would be small. Cumulative impacts related to urban noise would be small.

Vibration

In the Caliente and Mina rail alignment cumulative impacts regions of influence, other possible sources of vibration include occasional testing activities at the Nevada Test and Training Range and sonic booms from aircraft-related military activities in the airspace above the region of influence. These events would tend to be short-term and localized. Cumulative impacts from vibration would be small.

8.4.2.9 Socioeconomics

The economy in the Caliente rail alignment cumulative impacts region of influence has traditionally been based on mineral development and livestock grazing. However, the economy in the region of influence is changing, just as land uses are changing. New economic drivers include services, retirement communities, and tourism, including recreation opportunities. Population growth in the region of influence is projected to occur in existing residential areas such as Caliente and Tonopah, but also in new areas such as Coyote Springs and the Bureau of Land Management land-disposal areas in Lincoln County. Overall, the proposed railroad project would have small impacts on economic development and growth, housing and community infrastructure, and traffic in the Caliente rail alignment region of influence. While there would be some limited potential for induced growth impacts, the specific locations and scope of these actions is unknown at this time, and any such actions are projected to be small. Cumulative impacts to socioeconomics in the Caliente rail alignment region of influence would be small.

The economic roots of the Mina rail alignment cumulative impacts region of influence have traditionally been based on mineral development, military operations and support, and livestock grazing. These activities will continue to be the primary economic drivers in the region of influence. In addition, the expansion of the Reno-Carson City metropolitan area in the northern reaches of the region of influence will continue to occur, providing additional economic inputs. Population growth in the Mina rail alignment cumulative impacts region of influence has generally been stagnant in much of the area. Overall, the proposed railroad project would have a small impact on economic development and growth, housing and community infrastructure, and traffic in the Mina rail alignment region of influence. While there is some limited potential for induced growth impacts, the specific locations and scope of these actions is unknown at this time, and any such actions are projected to be small. Cumulative impacts to socioeconomics in the Mina rail alignment region of influence would be small.

8.4.2.10 Occupational and Public Health and Safety

The Rail Alignment EIS cumulative impact section evaluates two areas of occupational and public health and safety impacts: nonradiological and radiological.

Nonradiological health and safety. There are no data on injury or illness incident rates for the Caliente and Mina rail alignment cumulative impact regions of influence. Injury or illness incidence rates in Nevada generally run higher than those in the United States as a whole. The economic segments with the highest injury or illness incidence rates in Nevada are construction and goods-producing industries. Regional activities would cumulatively add to the totals beyond the railroad-related impacts. Other regional activities would also cumulatively add to the totals beyond the railroad-related impacts, but cumulative nonradiological health and safety impacts in the Caliente or Mina rail alignment region of influence would be small within the context of the overall region of influence.

Radiological heath and safety. For members of the public along the Caliente rail line, DOE estimated that there could be up to 1.3×10^{-4} latent cancer fatality, corresponding to a collective population dose of 0.2 person-rem. For members of the public along the Mina rail line, DOE estimated that there could be up to 8.5×10^{-4} latent cancer fatality, corresponding to a collective population dose of 1.4 person-rem. Operation of the proposed railroad along the Caliente or Mina rail alignment would result in a small contribution to cumulative radiological health and safety impacts. Cumulative radiological impacts in the Caliente or Mina rail alignment region of influence would be small.

8.4.2.11 Utilities, Energy, and Materials

The Rail Alignment EIS cumulative impact section evaluates two areas of utilities, energy, and materials impacts: (1) utilities and (2) energy and materials.

Utilities. Many regional activities, including the proposed railroad, would increase demands on public water systems, wastewater systems, telecommunications systems, electric power systems, and other utilities. However, regional service providers are projected to be able to adjust to any increasing demand, and overall cumulative impacts to utilities would be small.

Energy and materials. While the regional markets for various construction-related materials and energy sources will continue to grow as the region develops, there is no evidence of potential limits to growth from constrained material or energy supplies. Cumulative impacts from energy and materials use in the Caliente or Mina rail alignment region of influence would be small.

8.4.2.12 Hazardous Materials and Waste

The Rail Alignment EIS cumulative impact section evaluates two areas of hazardous materials and waste impacts: DOE waste management activities and sanitary and construction wastes.

DOE waste management activities. There are two active waste management and disposal sites on the Nevada Test Site: Area 5 occupies 2.9 square kilometers (720 acres) and is in Frenchman Flat north of Mercury, Nevada, and Area 3 occupies 0.52 square kilometer (130 acres) north of Mercury in Yucca Flat. There are no plans for Test Site activities to include use of the proposed railroad for shipment of wastes. The Caliente rail alignment would not contribute to cumulative DOE waste management activities on the Nevada Test Site. The Mina railroad's contribution to cumulative impacts associated with DOE waste management activities on the Nevada Test Site would be small.

Sanitary and construction wastes. Nevada has 24 operating municipal landfills with a combined capacity to accept more than 11,000 metric tons (12,000 tons) of waste per day. However, the number of operating landfills has decreased substantially over the past 15 years, and while there is sufficient capacity to accept waste for the State of Nevada as a whole, there are some areas such as Pahrump that have limited capacity for future years. Other major projects would have similar waste streams, and project plans and requirements would call for disposal of such wastes in permitted facilities and materials management according to accepted industry practices. The proposed railroad's contribution to impacts from the generation and management of sanitary and construction wastes would be small. Cumulative impacts to waste disposal facilities in the Caliente or Mina rail alignment region of influence would be small.

8.4.2.13 Cultural Resources

Mission activities occurring at the Nevada Test Site, the Nevada Test and Training Range, and the Yucca Mountain Repository could cause unintended adverse impacts to cultural resources. It is likely that only a portion of any currently undiscovered sites would be found eligible for inclusion in the *National Register of Historic Places*. Impacts to cultural resources in the Caliente or Mina rail alignment region of influence would be small because DOE would conduct intensive field surveys and implement mitigation measures, including avoidance. Other project proponents would be subject to the same regulatory framework and Bureau of Land Management policies and procedures. Cumulative impacts to cultural resources in the Caliente or Mina rail alignment region of influence would be small.

8.4.2.14 Paleontological Resources

The primary cumulative impact mechanisms that could affect paleontological resources include excavations or surface disturbances associated with approval and implementation of Bureau of Land Management rights-of-way, off-highway vehicle use, minerals development, land disposals, and special designations. Many Bureau of Land Management activities, however, protect and mitigate impacts to paleontological resources. Most formations that a Caliente or Mina rail line would cross are volcanic and would not contain paleontological resources. Therefore, a railroad in the Caliente or Mina rail alignment would not contribute to cumulative impacts to paleontological resources.

8.4.2.15 Environmental Justice

The Rail Alignment EIS cumulative impact section evaluates two areas of environmental justice impacts: potential effects to low-income and minority populations and economic opportunity.

Potential effects to low-income and minority populations. DOE has concluded that there would be no identifiable environmental or human health impacts associated with the proposed railroad that would disproportionately affect low-income or minority populations. In addition, there would be no effects to subsistence hunting and gathering traditions in the Caliente or Mina rail alignment region of influence. Cumulative impacts to low-income and minority populations in the Caliente or Mina rail alignment region of influence would be small, if any. The only moderate or large impacts that were identified relate to noise impacts from construction. These impacts would not occur on the Walker River Paiute Reservation, so there would be no large and adverse effects that would disproportionately affect a low-income or minority community, and there are no special pathways that would result in disproportionately large and adverse effects to low income or minority communities.

Economic opportunity. Any potential for economic gain would be distributed equally to persons or businesses in the area that sought employment or business opportunity for both the Caliente and Mina rail alignments. While not all persons would gain economically from the cumulative group of projects and activities, the opportunity for gain would not favor one population group or another based on minority or income status.

8.5 Cumulative Manufacturing Impacts

This section describes potential cumulative environmental impacts from the manufacture of repository components DOE would require to emplace Inventory Module 1 or 2 in the proposed repository. DOE has identified no adverse cumulative impacts from other federal, non-federal, or private actions because it has identified no actions that, when combined with the Proposed Action or Inventory Module 1 or 2, would exceed the capacity of existing manufacturing facilities.

The overall approach and analytical methods and the baseline data that DOE used for the evaluation of cumulative manufacturing impacts for Inventory Module 1 or 2 were the same as those discussed in Chapter 4, Section 4.1.14 for the Proposed Action. The evaluation focused on ways in which the manufacture of repository components could affect environmental resources at a representative manufacturing site and potential impacts to material sources and supplies.

Table 8-15 lists the total number of repository components DOE would require for the Proposed Action and Inventory Modules 1 and 2. The total number would increase by as much as 120 percent for Modules 1 and 2 in comparison to the Proposed Action. The highest total number of repository components would be for Module 2, so this was the number that DOE used in the cumulative impact analysis.

Table 8-15. Number of offsite-manufactured components required for the Proposed Action and Inventory Modules 1 and 2.

		Number to be manufactured[a]		
Component	Description	Proposed Action	Module 1	Module 2
Rail shipping casks or overpacks	Storage and shipment of SNF and HLW	79	99	99
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	30	30	30
Waste packages	Outside container for SNF and HLW for emplacement in the repository	11,200	25,700	26,300
TAD canisters	Standardized canisters to hold commercial SNF	7,400	14,300	14,300
Emplacement pallets	Support for emplaced waste packages	11,200	25,700	26,300
Drip shields	Titanium covers for waste packages	11,500	26,000	26,600
Aging overpacks	Metal and concrete storage vaults for aging	2,500	2,500	2,500
Shielded transfer casks	Casks for transfer of canisters between and in site facilities	6 to 10	10	10

a. The number of components is an approximation, but is based on the best available estimates.
HLW = High-level radioactive waste.
SNF = Spent nuclear fuel.
TAD = Transportation, aging, and disposal (canister).

DOE based the Proposed Action evaluation on a 24-year manufacturing period for all components other than the drip shields. This 24-year period kept pace with the repository facilities' maximum processing capacity and therefore was conservative (a longer manufacturing period would spread the impacts over a longer period). Because the Module 1 or 2 inventory would be roughly double that of the Proposed Action, it would take about twice as long for repository facilities to process the inventory at maximum capabilities. Therefore, this evaluation assumed a 48-year manufacturing period for repository components other than drip shields. Using similar logic, the evaluation also assumed the manufacture of the drip shields over a 20-year period rather than the 10-year period in the Proposed Action evaluation.

Because the total number of manufactured components would be slightly more than double those of the Proposed Action and the manufacturing periods have only doubled, there could be some increases in annual impacts. This would be most prevalent in the manufacture of drip shields, which would increase in number by 130 percent under the Module 2 inventory. The annual Module 2 impacts for air quality, socioeconomics, material use, and waste generation would be as much as 17 percent higher than those for drip shield manufacture in Chapter 4, Section 4.1.14 for the Proposed Action, and these impacts would continue for 20 years rather than the 10 years for the Proposed Action. The total number of worker injuries and illness or fatalities could increase in proportion to the increase in manufactured components. The potential number of reportable injuries and illnesses over the entire 68-year period for Module 1 or 2 could be about 3,400 and the estimated number of fatalities could be 1.2; that is, based on national averages for the type of work involved, a fatality could occur during the manufacture of repository components under Module 1 or 2. As for the Proposed Action, there would be few or no impacts on other resources because existing manufacturing facilities would meet projected manufacturing needs, new construction would not be necessary, and environmental justice impacts (that is, disproportionately high and adverse impacts to minority or low-income populations) would be unlikely.

8.6 Summary of Cumulative Impacts

This section summarizes the cumulative impacts DOE has discussed in this chapter. In addition, it presents the viewpoint of Nye County as a cooperating agency and site of the Proposed Action of this Repository SEIS.

8.6.1 CUMULATIVE IMPACTS FROM ALL SOURCES

Table 8-16 summarizes cumulative impacts from all sources. DOE has included qualitative descriptions if they are more meaningful than quantitative values, even though the previous sections might provide quantitative values. In other cases, quantitative values provide a better representation of potential impacts.

8.6.2 NYE COUNTY VIEWPOINT

This section presents the viewpoint of Nye County as a cooperating agency and situs county of the Proposed Action of this Repository SEIS.

Nye County would host the repository and associated facilities and would be the funnel through which all waste shipments converge for disposal, regardless of the final mode or method of transportation. The proposed repository is one of many federal and private sector actions that have affected, or have the potential to affect, county resources. About 93 percent of the total land area of Nye County is under the stewardship of federal agencies, which have conducted a wide range of activities, including atomic and conventional weapons testing and training, habitat and wilderness preservation, waste disposal, and resource development. Past, present, and reasonably foreseeable future activities by these agencies have direct and indirect cumulative impacts on the county environment and economy. These impacts are cumulative with activities in the private sector, including mining and milling, agriculture, and land

Table 8-16. Summary of cumulative impacts.

Resource area	Cumulative impact
Land use and ownership	The ownership, management, and use of the analyzed land withdrawal area would not change for Inventory Module 1 or 2. The amount of land for surface facilities would increase somewhat for Module 1 or 2 because of the larger excavated rock storage area and additional ventilation shafts for the larger repository. This would have no substantial cumulative land use or ownership impact.
	The Nye County Yucca Mountain Project Gateway Area Concept Plan is a land use concept to ensure orderly and compatible development for the area around the repository site entrance. Development could affect land use.
	Cumulative impacts to land use and ownership in the Caliente or Mina rail alignment region of influence would be small.
Air quality	The activities that produced releases of criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter) would be roughly the same for Inventory Module 1 or 2 as those described for the Proposed Action. The changes would be the increased land disturbance and particulate matter for the larger excavated rock storage area and additional ventilation shafts from the larger subsurface repository. In addition, the increase in the manufacturing of drip shields associated with Module 2 could result in 17-percent higher impacts from the drip shield impacts discussed in Chapter 4.
	Potential cumulative impacts to air quality and climate from construction and operation of a Caliente or Mina railroad would be small, but could approach moderate if the potential violations of the National Ambient Air Quality Standards occurred from quarry or staging yard construction.
Hydrology	
Surface water	Additional land disturbances for the emplacement of Inventory Module 1 or 2 would be small and in an area already altered for the Proposed Action. Changes to runoff, infiltration rates, natural drainage alteration, and contaminant movement in soil would not increase much from the Proposed Action.
	Cumulative impacts to surface water from the Caliente or Mina rail line would be small. One area of flooding concern is the Meadow Valley Wash area near the City of Caliente.
Groundwater	Anticipated impacts to groundwater from the emplacement of Inventory Modules 1 and 2 would be the same or very similar to those for the Proposed Action. This would include changes to infiltration, potential for contaminant migration, and potential to deplete groundwater resources.
	Water demand at the start of construction activities for the emplacement of Inventory Module 1 or 2 combined with the baseline demands from the Nevada Test Site could exceed the lowest value of perennial yield, but for only 1 year. The Advance Accelerator project proposed for the Test Site could increase water use and be cumulative with the Proposed Action. Potential also exists for impacts from the development in the proposed Yucca Mountain Project Gateway Area Concept Plan, which Nye County presented to manage development and minimize impacts.
	Overall, the needs of the proposed railroad would represent a small portion of the current cumulative water usage in the Caliente or Mina rail alignment region of influence, which in some locations would continue to exceed perennial yield values.

Table 8-16. Summary of cumulative impacts (continued).

Resource area	Cumulative impact
Biological resources and soils	Cumulative preclosure nonradiological impacts to biological resources would be similar to those for the Proposed Action. Those impacts would occur primarily as a result of site clearing, placement of material in the excavated rock storage pile, habitat loss, and the loss of individuals of some animal species during site clearing and from vehicle traffic. Inventory Module 1 or 2 would require disturbance of biological resources in a larger area than the Proposed Action would disturb, primarily because the excavated rock storage pile would be larger.
	Cumulative impacts to habitat loss, special status species, native species, wildfires in the Caliente or Mina rail alignment region of influence would be small.
Cultural resources	Cumulative preclosure impacts to cultural resources could increase slightly from those for the Proposed Action due to a slight increase in land disturbance for Inventory Module 1 or 2. The emplacement of either module would require small additional disturbances to land in areas DOE surveyed during site characterization activities and an increase in time of operation.
	Overall, the cumulative impacts to cultural resources in the Caliente or Mina rail alignment region of influence would be small because the Department would conduct intensive field surveys and implement mitigation measures, including avoidance.
	DOE would identify and evaluate cultural resources, as required by Section 106 of the National Historic Preservation Act, and would take appropriate measures to avoid or mitigate adverse impacts to such resources.
Socioeconomics	Cumulative preclosure impacts to socioeconomics would be similar to impacts for the Proposed Action. The increased inventory associated with Module 1 or 2 would not result in a larger number of employees, but would result in a longer operations period. Annual socioeconomic impacts would occur for a longer period. In addition, the increase in the manufacturing of drip shields associated with Module 2 could result in 17-percent higher impacts from the drip shield impacts discussed in Chapter 4.
	The proposed railroad project would have small cumulative impacts to economic development and growth, housing and community infrastructure, and traffic in the Caliente or Mina rail alignment region of influence would be small. While there is some limited potential for induced growth impacts, the specific locations and scope of these actions is unknown at this time, and any such actions are projected to be small. Overall, the cumulative impacts within the Caliente or Mina rail alignment region of influence would be small.
Occupational and public health and safety	
Nonradiological	The total estimated impacts from industrial hazards for Inventory Module 1 or 2 could increase by 50 percent over those impacts for the Proposed Action. The impacts from manufacturing for Modules 1 and 2 would increase in proportion to the increase in components manufactured and the potential number of reportable injuries and illnesses could be about 3,400 and the estimated number of fatalities could be 1.2.
	Cumulative nonradiological health and safety incidents in the Caliente or Mina rail alignment region of influence would be small within the context of the overall region of influence.

Table 8-16. Summary of cumulative impacts (continued).

Resource area	Cumulative impact
Radiological	Calculated values for latent cancer fatalities for repository workers during the construction, operation and monitoring, and closure periods for Module 1 or 2 could be in the range of 20 to 26 fatalities. These are about double those for the Proposed Action (9.6 to 13 fatalities). The likelihood that the maximally exposed individual could experience a latent cancer fatality would be less than 0.0006 for emplacement of Inventory Module 1 or 2. Cumulative radiological health and safety impacts in the Caliente or Mina rail alignment region of influence would be small.
Accidents	Disposal in the proposed repository of Inventory Module 1 or 2 would result in a very small increase in the estimated risk from accidents.
Noise	The emplacement of Inventory Module 1 or 2 would have noise levels associated with the construction and operation of the repository similar to those for the Proposed Action. An increase in potential noise impacts would be from the increased number of shipments and increased shipping time for Inventory Module 1 or 2. Construction and operation of a railroad along the Caliente or Mina rail alignment would introduce or expand some railroad noise into areas that previously had none. This could result in annoyance for some people. Cumulative impacts from noise and vibration in the Caliente or Mina rail alignment region of influence would be small.
Aesthetics	Because the profile of the repository facilities and the appearance of access roads would not change as a result of implementation of Inventory Modules 1 or 2, there would be no additional impacts. The Nye County Yucca Mountain Project Gateway Area Concept Plan is a land use concept to ensure orderly and compatible development for the area around the repository. Development could affect aesthetics. There are no know interactions of the proposed rail alignments with other reasonably foreseeable activities that would contribute to cumulative impacts to aesthetic resources in the Caliente or Mina rail alignment region of influence.
Utilities, energy, materials, and site services	Because the surface facilities and the annual throughput would be the same for Inventory Module 1 or 2 and the Proposed Action, annual impacts to electricity use, fossil fuel demand, and residential water and sewer services would be the same as those for the Proposed Action. These impacts would last for a longer duration due to the increased operations period. In addition, the increase in the manufacturing of drip shields associated with Module 2 could result in 17 percent higher impacts from the drip shield impacts discussed in Chapter 4. The Nye County Yucca Mountain Project Gateway Area Concept Plan is a land use concept to ensure orderly and compatible development for the area around the repository. Development could affect utilities, energy, materials, and services. Many regional activities, including the proposed Caliente or Mina railroads, would increase demands on utilities, energy, and materials. However, regional service providers are projected to be able to adjust to any increasing demand, and overall cumulative impacts would be small. Cumulative impacts in the Caliente or Mina rail alignment region of influence would be small.

Table 8-16. Summary of cumulative impacts (continued).

Resource area	Cumulative impact
Waste management	Because the surface facilities and the annual throughput would be the same for Inventory Module 1 or 2 and the Proposed Action, the annual production of waste types would be the same as that for the Proposed Action. These impacts would last for a longer duration due to the increased operations period. In addition, the increase in the manufacturing of drip shields associated with Module 2 could result in 17-percent higher impacts from the drip shield impacts discussed in Chapter 4. Other major projects in the Caliente or Mina region of influence would have similar waste streams, and project plans and requirements would call for disposal of such wastes in permitted facilities and materials management according to accepted industry practices. Cumulative impacts to waste management in the Caliente or Mina rail alignment region of influence would be small.
Environmental justice	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for Inventory Module 1 or 2 or the Caliente or Mina rail alignment. DOE recognizes that American Indian people who live in the region have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on access to the site.

development, although impacts from such activities could be offset by economic and other benefits to the county.

From the Nye County perspective, the impacts from the proposed repository would be cumulative with all past, present, and reasonably foreseeable future actions by the federal and private sectors. Therefore, in accordance with its status as a cooperating agency for this Repository SEIS, Nye County is providing its perspective on the cumulative impacts of the Proposed Action. DOE based the discussion in this section on the technical resource document prepared by the County (DIRS 182884-NWRPO 2007). This section provides an objective assessment that reflects the county's unique perspective on cumulative impacts.

8.6.2.1 Nye County's Assessment of Baseline Environment and Baseline Conditions

In Nye County's view, the baseline for the Proposed Action predates all historical repository-related actions, regardless of when the actions occurred. The conditions that currently exist in the regions of influence include impacts of past repository-related actions (for example, the segregation of certain land from mineral entry), and reflect direct or indirect impacts related to the repository program, rather than true baseline conditions. Nye County does not believe that the current existing conditions are the baseline against which DOE should measure repository and cumulative impacts.

Where the implementation of historical federal actions has affected Nye County (for example, withdrawal of public land from any form of public entry for the Nevada Test and Training Range and the Nevada Test Site), the existing conditions include the impacts associated with those actions. Those impacts contribute to the cumulative impacts of past federal actions and to the total cumulative impacts of federal and non-federal actions on the county.

8.6.2.2 Nye County's Assessment of Region of Influence

From the Nye County perspective, the region of influence should include Nye County in its entirety as well as the region around the county. The county recognizes that the region of influence that DOE considered for analysis of cumulative impacts will vary depending on the evaluated element of the affected environment, and that DOE should base its analysis on the region in which impacts could reasonably be expected to occur. For geology, cultural resources, noise, and biological resources and soils, the region of influence can be limited to only those areas that would be disturbed, or where activities would occur. The region of influence for air quality includes all topographic basins in which land disturbances or emissions would occur, and where additional urban development would occur as a result of employee in-migration. For socioeconomics and occupational and public health and safety, the region of influence potentially includes all of Nye County, and could include each potentially affected unit of local government and the State of Nevada. The region of influence for surface-water resources includes hydrographic basins in which DOE would take actions and any basins to which they are tributary. For groundwater resources, the region of influence includes the entire Death Valley regional flow system.

8.6.2.3 Nye County's Assessment of Impacts of Past and Present Federal and Private Sector Actions

Past and present actions by federal agencies in Nye County are characterized in four broad areas: (1) land withdrawals and designations; (2) conventional and nuclear weapons testing and training; (3) waste disposal operations; and (4) congressional mandates regarding land and resource uses. The Nye County technical resource document describes adverse and beneficial direct and indirect impacts from these actions (DIRS 182884-NWRPO 2007).

Federal agencies have withdrawn more than 10,500 square kilometers (2.6 million acres) in Nye County for missions that include the Nevada Test Site, Nevada Test and Training Range, Death Valley National Park, National Wildlife Refuges, and American Indian reservations. In addition, agencies have designated more than 240 square kilometers (59,000 acres) for conservation, wildlife, or preservation. These land withdrawals and designations have had or will have significant adverse impacts due to the loss of potential revenues to Nye County from restrictions on development of mineral, renewable energy, oil and gas, and water resources; loss of future productivity from the withdrawn lands; and significant alterations of transportation routes through road closures and lack of rights-of-way across withdrawn lands. The designation by the Bureau of Land Management of about 190 square kilometers (46,000 acres) of federal land in Nye County for disposal to the private sector will result in impacts on water availability, infrastructure, and the environment as development occurs. Impacts from private sector development could be offset by economic and other benefits to the county provided that appropriate resources are applied to ensure development occurs in a controlled manner. Nye County is preparing a Yucca Mountain Project Gateway Area Concept Plan to provide a basis for managing development near the gateway to the repository, but might not have adequate resources to implement the plan without support from DOE. The Proposed Action would permanently withdraw about 180 square kilometers (44,000 acres) of additional public land currently within the taxing district for the town of Amargosa Valley. The impacts of that withdrawal would be cumulative with the other land withdrawals and designations.

Above-ground and subsurface nuclear weapons tests, conventional weapons and weapons systems tests, firing ranges, and activities associated with these operations result in significant disturbances over hundreds of square kilometers. Significant adverse impacts have included blast and collapse craters, radioactive contamination of soils and groundwater, safety hazards from unexploded ordnance, fugitive emissions from contaminated soils, annoyance and startle effects from supersonic aircraft, and a remaining radionuclide burden of more than 300 million curies. Significant injury to natural resources, especially water resources, has occurred with a corresponding significant loss of long-term productivity.

Waste disposal actions have included disposal of about 9.8 million curies of radioactive wastes in craters, the Greater Confinement Disposal site, and the Area 5 Radioactive Waste Disposal Site on the Nevada Test Site; disposal of ordnance and other waste on U.S. Air Force and DOE lands; disposal of low-level radioactive waste and hazardous waste at a privately operated site near the community of Beatty; and disposal of municipal waste at Amargosa Valley and Pahrump. Impacts associated with the latter two actions are offset by economic and other benefits to the county. The proposed action would add a significant new contribution to the radioactive burden in the county; generate an appreciable volume of industrial and construction wastes; and result in an increased demand for municipal waste disposal capacity in employment and housing centers. If DOE transported the high-level radioactive wastes to the repository site without incident, and the repository performed at least as well as estimated by the Total System Performance Assessment (Chapter 5), no significant new impacts to the environment would result from waste disposal at the repository. However, releases of radioactive constituents during transportation and handling or after emplacement could have significant impacts. Stigma associated with waste disposal (and disposal of radioactive waste in particular) could be a significant impact, but would vary by demographics. Although Nye County does not perceive any stigma from the Proposed Action at this time, public perception and the stigma associated with nuclear waste and waste management facilities could attach to the county and affect in-migration, adding to cumulative impacts from the Proposed Action.

Congressional mandates for resource management, protection, and preservation have resulted in significant adverse impacts on Nye County through the imposition of severe restrictions on water, mineral, and land development, with a corresponding decrease in long-term productivity from those lands and loss of potential tax revenues. Impacts from the implementation of the *Nuclear Waste Policy Act* are cumulative with those of other congressional mandates.

8.6.2.4 Nye County's Perspective of Reasonably Foreseeable Future Actions

Reasonably foreseeable future actions considered in Nye County planning include both federal and non-federal actions that are likely to occur by 2050. Federal actions would include continued operations at the Nevada Test Site and the Nevada Test and Training Range; implementation of resource management and general management plans for national parks, wildlife refuges, and public lands; and construction, operation, and closure of a high-level nuclear waste repository at Yucca Mountain.

DOE based the identification of reasonably foreseeable actions by local government and the private sector on planning estimates of future population, land development patterns, and the availability of additional natural resources. Reasonably foreseeable actions by local government and the private sector should lead to an increase in population in Amargosa Valley to about 50,000 persons by 2050, with a corresponding population increase in Pahrump to about 150,000 persons. These projections do not include the incremental impacts from construction and operation of the proposed repository. All remaining farmland in Pahrump should be retired from agriculture by 2030 and agriculture in Amargosa Valley should cease by 2050. At least one new precious metal mine is likely to be permitted and opened in the southern part of the county in a rural, generally undeveloped area and have an operating life of 40 years or less. Dairy operations should cease in Pahrump by 2012 and in Amargosa Valley by 2040. The waste disposal site at Beatty is likely to continue operations for 20 years, after which state regulatory authorities will permit no hazardous, mixed-waste, or low-level waste disposal operations. All groundwater resources in the southern part of Nye County will be appropriated and placed to a beneficial use by 2050.

8.6.2.5 Nye County's Perspective of Cumulative Adverse Impacts

The cumulative adverse impacts of past, present, and future federal actions and mandates, are significant. The most significant adverse impact is from conventional and nuclear weapons testing activities that have contaminated isolated areas on DOE and U.S. Air Force-controlled lands, and massive and widespread soil and groundwater contamination in large areas on the Nevada Test Site. The Nye County Water Resources Plan (August 2004) estimated that the volume of groundwater contaminated from weapons testing is about 6.17 billion cubic meters (5 million acre-feet). This contamination has significantly reduced the water resources available for use in the county. Contamination of the soils and groundwater on DOE-controlled land is cumulative with that on and under Air Force-controlled lands, and contamination from other sources, which includes waste disposal activities by the federal and private sectors. Soil or groundwater contamination that occurred as a result of the Proposed Action would add to the contamination that has already accumulated, further decreasing the water resources available to the county and the long-term productivity of the contaminated areas.

The second most important adverse impact from past federal actions is the loss of access to lands due to withdrawal by DOE, the Department of Defense, and the Department of the Interior, and the designation of lands for environmental protection through National Parks, National Wildlife Refuges, and Areas of Critical Environmental Concern. More than 8,100 square kilometers (2 million acres) of land in Nye County are not available for the development of mineral and water resources. The withdrawal of additional land for the Proposed Action would add to the cumulative impact of the loss of lands for water and mineral resource development.

The third most important adverse impact from federal actions relates to the inventory of radioactivity that weapons testing and past and continuing radioactive waste disposal on the Nevada Test Site, as well as commercial disposal of low-level radioactive waste near Beatty have deposited in Nye County. In total, more than 300 million curies have been deposited at sites in Nye County, primarily on the Nevada Test Site. The Proposed Action would add an estimated 14 billion or more curies to this cumulative amount.

The last major category of adverse impacts is loss of local control as a result of congressional mandates and federal policies on land and resource use. Early federal policies led to the settlement and development of Nye County and the adverse as well as beneficial impacts from mining, ranching, farming, and urbanization that followed the implementation of these policies. In the mid-1900s, federal policies led to the development of vast weapons testing and military training programs that have resulted in significant adverse environmental impacts as discussed above. Subsequent federal policies aimed at environmental protection led to significant constraints on the development of resources the county needed to sustain its economic viability. Compliance with these more recent federal policies has resulted in reductions in employment in some sectors, increased costs for development of water and land resources, decreased tax revenues, and loss of long-term productivity for large areas in Nye County. DOE based the

Proposed Action on a legislative mandate (the *Nuclear Waste Policy Act*) that would impose further constraints on resource utilization and would be cumulative with the significant adverse impacts that have already occurred.

Although Nye County believes that these cumulative adverse impacts have occurred and would increase incrementally as a result of the Proposed Action, it also believes that many of the impacts could be addressed and mitigated through implementation of various, routine measures. Identification and implementation of such measures could be facilitated through consultation and cooperation between the county and DOE. In Chapter 9, Nye County presents its perspective on the types of measures that could be jointly pursued by DOE and Nye County to minimize and mitigate the expected incremental impacts of the Proposed Action.

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9

Best Management Practices and Management Actions To Mitigate Potential Adverse Environmental Impacts

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9. BEST MANAGEMENT PRACTICES AND MANAGEMENT ACTIONS TO MITIGATE POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

9.1 Introduction

This chapter describes mitigation measures that the U.S. Department of Energy (DOE or the Department) would implement to mitigate adverse impacts to the environment that could occur if the Department implemented the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

The Council on Environmental Quality defines mitigation as (40 CFR 1508.20):

“ (a) Avoiding the impact altogether by not taking a certain action or parts of an action.

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(e) Compensating for the impact by replacing or providing substitute resources or environments.”

The mitigation measures that DOE would implement fall into two categories: a general category called *best management practices* and a specific category called *management actions*. DOE has defined best management practices for this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250-S1D) (Repository SEIS) as the processes, techniques, procedures, or considerations it would employ to avoid or reduce the potential environmental impacts of its Proposed Action in a cost-effective manner while meeting the Yucca Mountain Repository project objectives. While best management practices are not regulatory requirements, they can overlap and support such requirements. Use of best management practices would not replace any local, state, or federal requirements. Best management practices are integral to the design, construction, and operation of the proposed Yucca Mountain Repository, and the current design incorporates them. Specific management actions DOE would take to mitigate potential adverse impacts of the Proposed Action include compliance with other government agency stipulations or specific guidance, coordination with government agencies or interested parties, implementation of DOE policy decisions, monitoring of relevant ongoing and future activities and, if appropriate, instituting corrective actions Corrective actions would include, for instance, limiting the degree or magnitude of the action; reducing or eliminating the impact over time by preservation and maintenance operations; and repairing, rehabilitating, or restoring the affected environment.

The impact avoidance and reduction framework DOE has used in this Repository SEIS includes the following:

- As Chapter 2 discusses, the Proposed Action would adhere to U.S. Nuclear Regulatory Commission (NRC) safety requirements in 10 CFR Part 63 for the construction, operation, monitoring, and closure of a geologic repository and follow or exceed the requirements of 10 CFR Part 71 for the transportation of spent nuclear fuel and high-level radioactive waste. The incorporation of safety factors and controls in the engineering design and operational procedures would help prevent accidents and thereby minimize potential releases to the environment.

- As Chapters 4 and 6 discuss, DOE would implement best management practices to mitigate potential environmental impacts it identified for the Proposed Action.

- In this chapter, DOE summarizes best management practices and presents the management actions it would undertake to further mitigate potentially adverse environmental impacts.

- Chapter 10 presents unavoidable adverse impacts that would remain after DOE implemented best management practices and management actions.

9.2 Yucca Mountain Repository

9.2.1 BEST MANAGEMENT PRACTICES

Chapter 9 of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, pp. 9-1 to 9-30) (Yucca Mountain FEIS) presented mitigation measures DOE determined it would implement or identified for consideration to reduce potential impacts from the construction, operation and monitoring, and eventual closure of proposed repository. This chapter summarizes, reorganizes, and incorporates by reference the mitigation measures presented in the Yucca Mountain FEIS. For this Repository SEIS, many of those mitigation measures are considered best management practices. Table 9-1 summarizes best management practices DOE has identified for this Repository SEIS.

9.2.2 MANAGEMENT ACTIONS

DOE is firmly committed to its implementation of sound stewardship practices that are protective of air, water, land, and cultural and ecological resources that repository activities could affect. DOE would accomplish its commitment through implementation of environmental management systems as part of its Integrated Safety Management Systems. This structured approach to adaptive management through monitoring is currently an active part of DOE’s management structure; DOE would continue this practice throughout the Proposed Action.

As part of the planning process, DOE would establish measurable environmental objectives, and set measurable goals and targets (for example, pollution prevention goals for reductions in waste generation). DOE would then implement programs, procedures, and controls for monitoring and measuring progress, document progress and, if appropriate, institute corrective actions. While environmental management systems are not a formal part of DOE’s *National Environmental Policy Act* (NEPA) process, DOE

Table 9-1. Summary of best management practices for potential environmental impacts of the proposed repository.

Environmental resource	Best management practice
Land use	• Reclaim lands disturbed during the construction process. • Reclaim lands disturbed by surface facilities as they are no longer needed.
Air quality	• Reduce fugitive dust emissions using standard dust control measures. • Reduce maximum fugitive dust by minimizing activities that were near each other. • Use fossil-fuel vehicles that meet at least the Tier 3 emission standards.
Surface water	• Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates. • Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. • Use erosion and runoff control features such as proper placement of pipe, grading, and use of rip-rap at these intersections to enhance the effectiveness of the bridges or culverts. • Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion. • In and near floodplains, follow reclamation guidelines. • Train employees in the handling, storage, distribution, and use of hazardous materials. • Conduct fueling operations and store hazardous materials and other chemicals in bermed areas. • Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills. • Use sediment-trapping devices such as hay or straw bales, fabric fences, and devices to control water flow and discharge to trap sediments moved by runoff. • Prepare and submit a Storm Water Pollution Prevention Plan consistent with state and federal standards for construction activities.
Groundwater	• Recycle water collected in subsurface areas for use in dust suppression and other activities. • Implement measures to minimize the potential for water use during operations that could interfere with waste isolation in the repository. • Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates. • Monitor to detect and define unanticipated spills, releases, or similar events.
Biological resources and soils	• Use measures to control erosion, dust, and particulate matter to lessen the consequences for biological resources and soils from repository construction, operation and monitoring, and closure. • Use dust suppression measures to minimize wind and other erosion and aid recovery on disturbed areas. • Conduct preconstruction surveys to ensure that work would not affect important biological resources and to determine the reclamation potential of sites. • Implement measures to relocate or avoid sensitive species. • Minimize groundbreaking or land clearing activities during the critical nesting period for migratory birds. • Before ground disturbing activities, collect data to plan for the restoration of disturbed areas and minimize impacts to sensitive habitats. • Phase construction to the extent practicable. Limit grading activities to the phase immediately under construction and limit ground disturbance to areas necessary for project-related construction activities.

Table 9-1. Summary of best management practices for potential environmental impacts of the proposed repository (continued).

Environmental resource	Best management practice
Cultural resources	• Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. • Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the research potential of sites. • If construction could threaten important archaeological resources, and modification or relocation of roads would not be reasonable, develop additional mitigation measures.
Occupational and public health and safety	• Use ventilation to keep radon levels low in subsurface areas. • Avoid erionite-bearing strata where practicable during repository construction and drift development. • If drilling encountered erionite, close operations in potentially affected areas until proper controls were in place. • Use high-efficiency particulate air filters or similar controls if drilling occurred in an area where there is potential for encountering erionite. • Use monitoring devices and respirators as appropriate. • Design task procedures to reduce the potential for accidents. • Implement health and safety procedures and administrative controls to minimize risks to construction and operations workers. • Develop and implement an Ordnance and Explosives Safety Construction Support Program applicable to construction activities. Include ordnance and explosives training for all construction personnel working in the areas designated by the U.S. Department of Defense as being at risk of containing unexploded ordnance.
Aesthetics	• Use exterior lighting only where needed to accomplish facility tasks. • Limit the height of exterior lighting units, • Use shielded or directional lighting to limit the effects of the lighting to areas where it is needed.
Utilities, energy, and materials	• Implement procedures and equipment that would minimize the use of utility services, energy, and materials. • Incorporate high-performance and sustainable building criteria into the design and construction of non-nuclear facilities.
Waste and hazardous materials	• Recycle wastewater to reduce the amount of water needed for repository facilities and the amount of wastewater that could require disposal. • Use decontamination techniques that would reduce waste generation in comparison with other techniques. • Institute preventive maintenance and inventory management programs to minimize waste from breakdowns and overstocking. • Whenever practicable, recycle nonradioactive materials such as paper, plastic, glass, nonferrous metals, steel, fluorescent bulbs, shipping containers, oils, and lubricants rather than dispose of them. • Encourage the reuse of materials and the use of recycled materials. • Avoid use of hazardous materials where feasible. • Develop a spill prevention plan for petroleum products and other hazardous materials. • Ensure that equipment is available to respond to spills and identify the location of such equipment. • Dispose of drill cuttings through land application. • Inspect and replace worn or damaged components. • Implement an Environmental Management System and a Pollution Prevention/ Waste Minimization Program. • Salvage extra materials and use for other construction activities or for regrading activities.

encourages the integration of NEPA and environmental management systems. The structure of the Integrated Safety Management System/Environmental Management System fully supports mitigation of impacts DOE has identified in this Repository SEIS.

To minimize potential impacts from the Proposed Action, DOE is evaluating the preparation of a Mitigation Action Plan that identifies specific commitments for mitigation of adverse environmental impacts due to the Proposed Action. The plan would describe specific actions DOE would take to implement mitigation commitments and would reflect available information about the course of action. DOE could revise this Plan as more specific and detailed information became available. The Mitigation Action Plan would incorporate all practicable measures to avoid or minimize adverse environmental and human health impacts that could result from the Proposed Action and include the environmental management system.

DOE would conduct monitoring activities during all phases of the project to ensure the appropriate implementation of the Proposed Action and to ensure mitigation of impacts. The following are examples of activities DOE would conduct:

- Conduct the performance confirmation program, which consists of tests, experiments, and analyses during all periods of the repository project, to evaluate the accuracy and adequacy of the information DOE uses to determine with reasonable assurance that the repository would meet the performance objective for the period after permanent closure.

- Monitor groundwater quality, air emissions, and the repository workplace to ensure worker safety and other aspects of project interaction with the natural and human environment.

- Conduct cultural resource monitoring as appropriate before and during surface disturbance activities to identify and assess the potential for impacts to previously unidentified archaeological resources.

- Monitor emplaced waste in the repository starting with the first waste package emplacement and continuing through closure.

- After completion of emplacement, continue to monitor and inspect waste packages and continue performance activities.

- After sealing the repository openings, conduct postclosure monitoring to ensure acceptable repository performance. Details of this program would be defined during processing of the license amendment for repository closure.

DOE currently uses the following measures as part of its environmental management system and would continue to use them upon implementation of the Proposed Action:

- Provide assistance to state or local governments to mitigate economic, social, public health and safety, and environmental impacts under Section 116(c) of the *Nuclear Waste Policy Act*, as amended (NWPA) (42 U.S.C. 10101 et seq.).

- Observe all terms and conditions, reporting requirements, and conservation recommendations in the U.S. Fish and Wildlife Service Final Biological Opinion (DIRS 155970-DOE 2002, Appendix O), which includes five reasonable and prudent measures to minimize impacts to the desert tortoise and 18 terms and conditions with which DOE must comply to implement the five measures.

- Continue the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with American Indian tribes and to concentrate on the continued protection of important cultural resources.
- Continue to abide by Section 106 of the *National Historic Preservation Act of 1966* (16 U.S.C. 470) process while the draft programmatic agreement among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Office is being negotiated.

9.2.3 NYE COUNTY PERSPECTIVE ON MANAGEMENT ACTIONS TO MITIGATE POTENTIAL ADVERSE IMPACTS

This section presents the viewpoint of Nye County as a cooperating agency and situs county of the Proposed Action of this Repository SEIS.

As discussed in the Nye County Viewpoint presented in Section 8.6.2, the county believes that the majority of the direct and indirect cumulative impacts of past and on-going federal actions, as well as those incremental impacts that can be reasonably expected to occur if the Proposed Action is implemented, can be effectively mitigated. Even the groundwater contamination that resulted from nuclear testing, although not directly remediable, can be addressed through management actions.

Nye County believes that DOE's evaluation in this SEIS of potential impacts from the Proposed Action has been adequately rigorous. Because of differences in perspective between DOE and Nye County, however, coupled with uncertainty about future conditions, the county believes that the conclusions about potential impacts presented in this SEIS should be continuously assessed and evaluated through an appropriate monitoring program.

Nye County believes that the most prudent course of action, should the Proposed Action be implemented, would be to include an aggressive and comprehensive program of environmental monitoring, including monitoring of socioeconomic factors. As the local jurisdiction affected by the Proposed Action and as a cooperating agency in the preparation of this SEIS, Nye County's view is that there is mutual benefit for the federal and local government in partnering to monitor, assess, and evaluate conditions at and around the repository site as repository-related activities take place. In this way, Nye County can assist DOE in the identification of any potential impacts, whether significant or not, and cooperatively develop effective and efficient mitigations, as appropriate, through ongoing adaptive management.

Nye County proposes to constructively engage DOE to assist in identifying the resource areas that it believes will be susceptible to further impacts. Such identification would be based on the County's perspective on cumulative impacts as presented in Section 8.6.2, and on the results of DOE's analyses presented in the body and appendices of this SEIS. Nye County believes that such mutual consultation and cooperation should be formalized through agreements similar to those established by DOE for the Waste Isolation Pilot Plant in New Mexico.

9.3 Transportation

Transportation-related mitigation measures that DOE identified in the Yucca Mountain FEIS included measures for national transportation impacts and State of Nevada transportation impacts. Since completion of the Yucca Mountain FEIS, DOE issued a policy statement for waste shipments to Yucca Mountain. Chapter 2, Sections 2.1.7.2 and 2.1.7.3 and Chapter 6 of this Repository SEIS discuss this in detail. Briefly, DOE would use dedicated trains for most waste shipments and thereby derive benefits in safety, security, cost, and operations. DOE has updated the mitigation measures with the measures in Chapter 6 of this Repository SEIS and in the Rail Alignment EIS. The following sections discuss the best management practices and mitigation measures for national and Nevada transportation activities.

9.3.1 NATIONAL TRANSPORTATION

As Chapter 6 describes, the potential impacts from national transportation activities would occur primarily to occupational and public health and safety. Because the Proposed Action shipments would represent a relatively small incremental increase in national highway or rail traffic, they would have little or no measurable impacts on other resource areas. As such, the best management practices DOE implemented during the proposed transportation of spent nuclear fuel and high-level radioactive waste would be those that improved the protection of workers and the public. Appendix H of this Repository SEIS includes detailed descriptions of supplemental information about transportation activities for the Proposed Action. This information includes discussions of transportation regulations, operational practices, cask safety and testing programs, emergency response, security, and liability.

As indicated in the Yucca Mountain FEIS, Section 180(c) of the NWPA allows DOE to provide technical assistance and funds to states for training local government and American Indian tribal public safety officials through whose jurisdictions DOE could plan to transport spent nuclear fuel or high-level radioactive waste. As a specific management action to mitigate impacts, DOE could provide such training. The training would cover procedures for safe, routine transportation and for emergency response situations.

The shipment of spent nuclear fuel and high-level radioactive waste is highly regulated and subject to the utmost scrutiny. DOE carefully follows the U.S. Department of Transportation and NRC transportation rules now and will follow or exceed any future rules that may be established by Congress, the Department of Transportation, or NRC.

9.3.2 NEVADA TRANSPORTATION

Chapter 7 of the Rail Alignment EIS presents information about best management practices and mitigation in relation to the construction and operation of a rail line in Nevada. The chapter presents information drawn from the analysis of the Proposed Action and Shared-Use Alternative and consolidates information from the environmental consequences and mitigation analyses.

REFERENCES

155970 DOE 2002 DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE/EIS-250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314: MOL.20020524.0315; MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319; MOL.20020524.0320.

10

Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitment of Resources

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10. UNAVOIDABLE ADVERSE IMPACTS; SHORT-TERM USES AND LONG-TERM PRODUCTIVITY; AND IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain repository and the associated transportation of spent nuclear fuel and high-level radioactive waste could produce some environmental impacts that the U.S. Department of Energy (DOE or the Department) could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources. This chapter discusses unavoidable adverse impacts, short-term uses versus long-term productivity, and irreversible or irretrievable commitment of resources.

In keeping with previous chapters of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS), this chapter contains discussions of the repository, national transportation, and transportation in the State of Nevada. This chapter summarizes, incorporates by reference, and updates Chapter 10 of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, pp. 10-1 to 10-14) (Yucca Mountain FEIS). This chapter also incorporates by reference the information presented in Chapter 8 of the Rail Alignment EIS.

10.1 Unavoidable Adverse Impacts

This section summarizes potential impacts due to the Proposed Action (Chapter 4) that would be unavoidable and adverse and that would remain after DOE implemented best management practices and mitigation measures, which are discussed in Chapters 4, 6, and 9 of this Repository SEIS, and references Chapter 8 of the Rail Alignment EIS.

10.1.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes unavoidable adverse impacts from the construction, operation and monitoring, and closure of the proposed repository. This Repository SEIS provides estimated potential environmental impacts in Chapter 4, Section 4.1. Adverse impacts that would remain after implementation of best management practices and the institution of mitigation measures are unavoidable adverse impacts.

10.1.1.1 Land Use

To develop a Yucca Mountain repository, DOE would obtain permanent control of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force (Nevada Test and Training Range), and DOE (Nevada Test Site) lands in southern Nevada (Chapter 3, Section 3.1.1). If Congress authorized and directed the withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal. The conditions of withdrawal would permanently withdraw the land from any form of entry, appropriation, or disposal under the public land laws.

As Chapter 4, Section 4.1.1 discusses, DOE would disturb or clear land for subsurface and surface facility activities during the construction and operations periods. The total land disturbance for the proposed repository would be 9.7 square kilometers (2,400 acres), which would include land inside and outside the land withdrawal area. In addition, DOE could disturb an additional 0.4 square kilometer (100 acres) of land for a quarry for aggregate and fill material for the repository outside the analyzed land withdrawal area.

10.1.1.2 Air Quality

Construction, operation and monitoring, and closure of a repository at Yucca Mountain would produce small impacts to regional air quality. During construction, land disturbance and rock excavation would produce fugitive dust emissions, as would the operation of concrete batch plants (Chapter 4, Section 4.1.2). DOE would control most of these emissions with dust suppression methods. During construction and operations, construction equipment and other machinery would emit nitrogen dioxide, sulfur dioxide, and carbon dioxide. Exposures of maximally exposed individuals to these criteria pollutants would be a small fraction of applicable regulatory limits. Other impacts would come from materials such as cristobalite and erionite. Chapter 4, Section 4.1.2 discusses emission of cristobalite and erionite particles from the subsurface exhaust ventilation system during excavation operations.

Radiological impacts could occur from the release of radionuclides. The principal radionuclide release from the subsurface would be naturally occurring radon-222 and its decay products in ventilation exhaust air.

10.1.1.3 Hydrology

As Chapter 4, Section 4.1.3 notes, repository construction and operations would result in minor changes to runoff and infiltration rates and minimal alteration of natural surface-water drainage channels. Repository activity would result in the unavoidable crossing of washes that are designated as floodplains. The potential for flooding that could cause damage would be small.

Potential contaminants that could spill during construction would consist mostly of fuels (diesel, propane, and gasoline) and lubricants (oils and grease) for equipment. DOE would construct and install fuel storage tanks early in the construction period with appropriate secondary containment. Other potential contaminants such as paints, solvents, strippers, and concrete additives would be present in small quantities. DOE would minimize the potential for spills to occur and, if they occurred, would minimize contamination by following its *Spill Prevention, Control, and Countermeasures Plan for Site Activities* (DIRS 172055-DOE 2004, all).

DOE would withdraw groundwater during construction and operations. The highest annual water demand for the Proposed Action would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats hydrographic area (DIRS 105034-Turnipseed 1992, pp. 9 and 12). The Proposed Action would withdraw groundwater that would otherwise move into aquifers of the Amargosa Desert, but the combined water demand for the repository and Nevada Test Site activities in Jackass Flats would, at most, have minor impacts on the availability of groundwater in the Amargosa Desert area in comparison with the quantities of water already being withdrawn there. In addition, DOE could implement a series of infrastructure improvements before construction of the repository that would result in small additional groundwater withdrawals from the Jackass Flats basin (Chapter 4, Section 4.3). The estimate of water demand for the Proposed Action presented in Section 4.1.3.2.3 includes water requirements for the proposed infrastructure improvements.

10.1.1.4 Biological Resources and Soils

As Chapter 4, Section 4.1.4 notes, the construction of surface facilities and the disposition of excavated rock from subsurface construction would remove or alter vegetation in the land withdrawal area and within the 37-square-kilometer (9,100-acre) offsite area directly to the south. Removal of vegetation would result in impacts to small amounts of widely distributed land cover types that are not under-represented in the affected area. The largest losses would be to the Sonora-Mojave mixed salt desert scrub, with disturbance of approximately 0.15 percent of this land cover type in the affected area. The removal of vegetation could result in colonization by invasive plant species, which could suppress native species. DOE would use reclamation methods that would reduce the likelihood that invasive species would overtake species on reclaimed lands.

Direct impacts to biological resources would occur through: (1) loss of habitat from construction of facilities and infrastructure; (2) localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles during land disturbances, and deaths of individual animals from vehicle collisions; (3) fragmentation of undisturbed habitat that could create a barrier to the movement of individual species; and (4) displacement because of an aversion to the noise and activity of construction, operation and monitoring, and closure of the repository. DOE anticipates that the effect of the impacts to biological resources would be small because habitats similar to those at Yucca Mountain are widespread locally and regionally. The species that occur at the site are generally widespread throughout the Mojave or Great Basin deserts, and the deaths of some individuals due to proposed repository activities would have little impact on the regional populations of those species or on the overall biodiversity of the region. Large areas of undisturbed and unfragmented habitat would be available away from disturbed areas and impacts to wildlife from noise and vibration would occur only near the source of the noise.

The desert tortoise is the only species in the analyzed land withdrawal area listed as threatened under the *Endangered Species Act*, as amended (16 U.S.C. 1531 et seq.). There are no endangered or candidate species and no species that are proposed for listing. Repository construction would result in the loss of a very small portion of the desert tortoise habitat at the northern edge of its range in an area where the abundance of desert tortoises is low.

Several species sensitive by the Bureau of Land Management occur in the region of influence. Impacts to bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl from disturbance and loss of individuals would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Impacts to the Western red-tailed skink would be very small because it is widespread regionally and occupies small pockets of isolated habitat that would not be overly affected by any proposed disturbances. One species of insect, Giuliani's dune scarab beetle, has been reported only in the southern portion of the land withdrawal area away from any proposed disturbances, and therefore would not be affected.

Construction and operations activities at the proposed repository would disturb land and expose bare soil to wind and water erosion. Studies during Yucca Mountain site characterization work and experience at the Nevada Test Site indicate that natural succession on disturbed arid land would be a very slow process

(Chapter 4, Section 4.1.4.3.2). Soil recovery would be unlikely without reclamation. DOE is committed to reclamation of disturbed areas.

10.1.1.5 Cultural Resources

In the Yucca Mountain FEIS, DOE provided a summary of the American Indian view of cultural resource management and preservation. In the view of American Indians, the implementation of the Proposed Action would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of American Indians, represent an irreversible impact to traditional lands. That perspective in the context of this section would therefore indicate that any action would result in unavoidable adverse impacts.

Some unavoidable adverse impacts could occur to archaeological sites and other cultural resources. There could be a loss of archaeological information due to illicit artifact collection. In addition, excavation activities could cause a loss of archaeological information. Chapter 4, Section 4.1.5 discusses impacts to cultural resources in the region of influence.

10.1.1.6 Socioeconomics

The construction, operation and monitoring, and closure of a repository at Yucca Mountain would result in increased employment and population, which would place increased demands on housing and public services such as public safety and schools (Chapter 4, Section 4.1.6), particularly in Nye County and other locations in the region of influence where the populations are smaller and existing infrastructure is less developed. However, the increases would in southern Nevada as a whole, and the metropolitan Las Vegas area in particular, would be small in comparison to total employment, population, real disposable income, Gross Regional Product, and state and local government spending in the region of influence.

For the five socioeconomic parameters DOE evaluated for this Repository SEIS, the changes in economic parameters would increase by less than 1 percent over the projected baseline values (Chapter 3, Section 3.1.6). The less-than-1-percent estimate assumes historical residential patterns. The potential impacts could be greater than a 1-percent change over baseline for communities in Nye County and elsewhere in the region of influence if more of the onsite workers and their families chose to live outside the Las Vegas/Clark County area.

10.1.1.7 Occupational and Public Health and Safety

There would be a potential for injuries or fatalities to workers from facility construction and operations due to common industrial accidents and inhalation of cristobalite and erionite. Engineering controls and training and safety programs would reduce but not eliminate the potential for worker injuries or fatalities. Chapter 4, Section 4.1.7.1 discusses nonradiological occupational and public health and safety issues.

Chapter 4, Section 4.1.7.2 discusses potential radiological impacts to workers and the public. The types of potential health and safety impacts to workers during the construction period would include those from exposure to naturally occurring radionuclides (primarily radon-222 and its decay products). Engineering controls and training and safety programs would reduce but not eliminate the potential. During the operations period, radiological impacts to workers could occur during the receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste. Monitoring of emplaced waste packages would also result in some exposures.

Members of the public could be exposed to airborne releases of radon-222 and its decay products from the subsurface exhaust ventilation air throughout the construction, operations, monitoring, and closure periods. Table 4-23 lists the estimated individual risk of contracting a latent cancer for the maximally exposed member of the public and the exposed population within 80 kilometers (50 miles) of the repository for all periods of project construction, operation, monitoring, and closure.

10.1.1.8 Utilities, Energy, Materials, and Site Services

The construction, operation and monitoring, and closure of a repository at Yucca Mountain would result in the unavoidable use of energy (mostly electricity and petroleum products) and material (mostly cement, steel, and copper). In addition, DOE would consume titanium in the manufacture of drip shields. The consumption of energy and construction material would not be large enough to affect national or regional supplies. Chapter 4, Section 4.1.11 lists the amounts of resources the Proposed Action would consume. Chapter 4, Section 4.1.14 presents information on the quantities of materials required for the manufacture of repository components such as the titanium required for drip shields.

In relation to site services, DOE would respond to and mitigate most onsite incidents, which would include underground incidents, without outside support (Chapter 4, Section 4.1.11.1.7). The Fire, Rescue, and Medical Facility would provide space for fire protection, firefighting services, underground rescue services, emergency and occupational medical services, and radiation protection. A helicopter pad would enable emergency evacuations. DOE would coordinate the operation of this facility with facilities in Nye County and at the Nevada Test Site to increase response capabilities.

Traffic volumes along U.S. Highway 95 would increase as a result of repository construction and operations. Increased traffic could result in more accidents, which could affect Nye County law enforcement and emergency services.

10.1.2 NATIONAL TRANSPORTATION

Chapter 6 identifies the following unavoidable impacts from the transportation of spent nuclear fuel and high-level waste from 72 commercial and 4 DOE sites to a siding for the Mina or Caliente rail corridor.

10.1.2.1 Occupational and Public Health and Safety

Certain adverse impacts to workers and the public from the transportation of spent nuclear fuel and high-level radioactive waste would be unavoidable. The loading and transportation of these materials would have the potential to affect workers and the public through industrial accidents, exposure to radiation and vehicle emissions, and traffic accidents.

10.1.2.1.1 *Impacts from Loading Canisters at Generator Sites*

DOE estimated the following impacts could occur from loading activities at the generator sites:

- About 1.2 traffic fatalities and about 0.23 fatality from vehicle emissions would result from shipping about 6,500 empty TAD canisters and 4,900 campaign kits to generator sites. Chapter 6, Section 6.2.1 presents a discussion of the transportation of canisters to generator sites.

- The *population dose* to members of the public within 16 kilometers (10 miles) of the generator sites would be 2.9 person-rem over the duration of loading operations. In the exposed population, the estimated probability of a latent cancer fatality would be 0.0017 or about 1 chance in 600. The estimated radiation dose to the maximally exposed member of the public 800 meters (0.5 mile) from a generator site would be 7.7×10^{-6} rem. The estimated probability of a latent cancer fatality for this individual would be 4.6×10^{-9} or about 1 chance in 200 million.

- The collective radiation dose for workers who performed loading activities would be 10,000 person-rem. In the exposed population of workers, this radiation dose would to result in 6 latent cancer fatalities.

10.1.2.1.2 *Incident-Free Transportation*

DOE estimated the following impacts could occur from incident-free transportation of spent nuclear fuel and high-level radioactive waste to Nevada:

- About 4 latent cancer fatalities could occur in the population of transportation workers who would be exposed to radiation from the shipments. Because many workers would be involved, the risk for an individual worker would be small.

- There would be about 1 (0.7) latent cancer fatality among members of the public who would be exposed to radiation. Because this estimate is for the entire population of individuals who would be exposed along the transportation routes over the course of shipments to the repository, the risk for a single individual would be small.

- The number of vehicles bound for Yucca Mountain would be very small in relation to normal traffic volume, which would result in a very small impact on air quality.

10.1.3 NEVADA TRANSPORTATION

Chapter 8 of the Rail Alignment EIS and Chapter 10, Section 10.1.3 of the Yucca Mountain FEIS present information about unavoidable adverse impacts related to the construction and operation of a railroad in Nevada. The chapter presents information drawn from the analysis of the Proposed Action and Shared-Use Alternative and consolidates information from the environmental impacts and mitigation analyses. The chapter addresses all environmental resource categories with an emphasis on those that could experience unavoidable adverse impacts.

10.2 Relationship Between Short-Term Uses and Long-Term Productivity

The Proposed Action would require short-term uses of the environment that would affect long-term environmental productivity. This section describes possible impacts to long-term productivity from those short-term uses.

This Repository SEIS identified two distinct periods for the evaluation of the use of the environment by the Proposed Action:

- A 105-year period for surface activities that would consist of construction, operation and monitoring, and closure of the proposed repository. DOE activities during this period would include construction of facilities, receipt and emplacement of spent nuclear fuel and high-level radioactive waste, recovery of recyclable materials, ventilation of subsurface emplacement areas, decontamination, closure of surface and subsurface facilities, reclamation of land, and monitoring. This period would be the only time during which DOE would involve the surface of the land used for the repository.

- The balance of a 1-million-year period that would consist of an evaluation of impacts from the disposal of spent nuclear fuel and high-level radioactive waste for the first 10,000 years and an evaluation of impacts for up to 1 million years.

In general, transportation and disposal activities associated with the proposed repository would benefit long-term productivity by the removal of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites around the country. In addition, removing these materials from existing sites would free people and resources committed—now and in the future—to the monitoring and safeguarding of these materials for other potentially more productive activities. Removal could create conditions that would enable the initiation of other productive uses at the commercial and DOE sites. Finally, disposing of spent nuclear fuel and high-level radioactive waste in the proposed repository would provide a long-term global benefit by isolating the materials from concentrations of human population and human activity, thereby reducing the potential for sabotage.

10.2.1 YUCCA MOUNTAIN REPOSITORY

In the Yucca Mountain FEIS, DOE described “short-term” as the time from start of construction to the end of relevant surface and subsurface human activity and “long-term” as the time from the end of the short-term period to the time environmental resources had recovered from the potential for impacts and were again productive, or a maximum of 1,000,000 years. “Productivity” refers to the ability of an element of the environment to generate crops, provide habitat, or otherwise serve as a medium for the creation of value. For transportation purposes, short-term refers to the time of construction or actual transportation, and long-term refers to the time from end of the short-term period to the time of environmental recovery.

10.2.1.1 Land Use

The withdrawal of land for the repository would total about 600 square kilometers (150,000 acres), which would include about 180 square kilometers (45,000 acres) in the town of Amargosa Valley taxing district, resulting in loss of productivity. The repository, however, would enable consideration of other uses for sites where spent nuclear fuel and high-level radioactive waste are being stored and the land buffering those sites. Many present storage sites are in locations that would permit a wider range of alternative uses than would Yucca Mountain.

10.2.1.2 Hydrology

As noted in Chapter 3, Section 3.1.4 of this Repository SEIS, the proposed repository is in the Alkali Flat-Furnace Creek hydrologic basin, which discharges to the Death Valley hydrologic basin. The Death Valley basin is hydrologically isolated and separated from other surface and subsurface water. Once water enters the Death Valley basin it can leave only by evapotranspiration. There would, however, be the potential for materials disposed of at the proposed repository to reach groundwater at some time between several thousand and 1 million years. If such contamination reached groundwater, and if the water exceeded applicable regulatory requirements, there could be an attendant loss of productivity for the affected groundwater and for surface waters in the basin. Conversely, the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would free a wide range of major and minor water bodies throughout the United States from the potential threat of radioactive contamination from the materials at the present storage sites.

10.2.1.3 Biological Resources and Soils

As described in Chapter 4, Section 4.1.4 of this Repository SEIS, biological resources would be affected directly by land disturbances. The overall impact to populations of species would be limited because the area disturbed and the number of individual animals lost would be small in relation to the regional availability.

Long-term productivity loss for soils would be limited to areas affected by land disturbances. DOE would revegetate these areas after the completion of closure activities. The disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would remove these materials from proximity to biota near the present storage sites across the United States.

10.2.2 TRANSPORTATION ACTIONS

Chapter 8 of the Rail Alignment EIS presents information on short-term uses and long-term productivity related to the construction and operation of a railroad in Nevada. The chapter presents information drawn from the analysis of the Proposed Action and Shared-Use Alternative and consolidates information from the environmental impacts and mitigation analyses.

The major long-term benefit of the transportation of spent nuclear fuel and high-level radioactive waste to the repository would be the permanent consolidation of these materials in an isolated location away from concentrations of people, with highly limited long-term exposure pathways to such concentrations.

10.3 Irreversible or Irretrievable Commitment of Resources

The Proposed Action would involve the irreversible or irretrievable commitment of land, energy, and materials. The commitment of a resource is irreversible if its primary or secondary impacts limit future options for the resource. An irretrievable commitment refers to the use or consumption of resources that are neither renewable nor recoverable for later use by future generations. Construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain would result in a permanent commitment of land, groundwater, surface, subsurface, mineral, biological, soil, and air resources; materials such as steel, titanium, and concrete; and energy in forms such as fossil fuels and electricity. Water use would support construction, operation and monitoring, and closure of the proposed repository and construction of the proposed Yucca Mountain Railroad. Radiological contamination of groundwater beyond safe levels, although not likely (Chapter 5), could limit future groundwater uses. There would be an irreversible and irretrievable commitment of natural resources such as land use and habitat productivity.

10.3.1 YUCCA MOUNTAIN REPOSITORY

Construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain would result in a permanent commitment of the land withdrawal area, including about 180 square kilometers (45,000 acres) in the town of Amargosa Valley taxing district, which would include surface and subsurface resources. The public could not make use of resources in that area.

Mitigation approaches that would involve the excavation of archaeological sites to prevent degradation by construction activities would destroy the contexts of those sites and reduce the finite number of such resources in the region. DOE expects that its activities at the proposed repository would affect no more than a minimal number of such sites.

Electric power, fossil fuels, and construction materials would be irreversibly committed to the project. Aggregate would be crushed and mixed in concrete for use in the repository. Chromium, molybdenum, nickel, and steel used to manufacture the transportation, aging, and disposal canisters as well as the titanium used in drip shields would be an irreversible and irretrievable commitment of resources. Some copper and steel ramps and access mains to subsurface facilities would be recyclable, while some in the emplacement drifts would be irreversibly an irretrievably lost. Most of the steel used for the surface facilities would be recyclable and, therefore, not an irreversible or irretrievable commitment. Some steel, such as rebar, would be difficult to recycle. The quantity of resources consumed would be small in comparison to their national consumption or their availability to consumers in southern Nevada.

10.3.2 TRANSPORTATION ACTIONS

The manufacture of transportation casks would require commitment of aluminum, chromium, copper, depleted uranium, lead, molybdenum, nickel and steel. With the exception of nickel, the required amounts of these materials would be low in relation to U.S. production and supply. The shipment of spent nuclear fuel and high-level radioactive waste to Nevada would involve irreversible commitments of electric power, fossil fuels, and construction materials.

Chapter 8 of the Rail Alignment EIS presents information on irreversible and irretrievable commitment of resources related to the construction and operation of a railroad in Nevada. The chapter presents information drawn from the analysis of the Proposed Action and Shared-Use Alternative and consolidates information from the environmental impacts and mitigation analyses.

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11

Statutory and Other Applicable Requirements

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11. STATUTORY AND OTHER APPLICABLE REQUIREMENTS

This chapter identifies major requirements that could be applicable to the *Proposed Action*, which is to construct, operate and monitor, and eventually close a *geologic repository* for the *disposal* of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain. Under the Proposed Action, the U.S. Department of Energy (DOE or the Department) would transport most spent nuclear fuel and high-level *radioactive* waste from 72 commercial and 4 DOE sites to the *repository* in *transportation casks* certified by the U.S. Nuclear Regulatory Commission (NRC) on trains dedicated only to these *shipments.* DOE would make some shipments, however, by truck over the nation's highways.

On February 14, 2002, the Secretary of Energy, in accordance with the *Nuclear Waste Policy Act*, as amended (42 U.S.C. 10101 et seq.) (NWPA), transmitted the recommendation, and the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS), to the President for approval of the *Yucca Mountain site* for development of a *geologic* repository. The President considered the site to qualify for application to NRC for a construction authorization and recommended the site to Congress. On July 23, 2002, the President signed the *Yucca Mountain Development Act of 2002* (Public Law 107-200; 116 Stat. 735), which approved the Yucca Mountain site for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. In referring to acts of Congress, this chapter refers to the law as amended in the United States Code, or it refers to the unamended act by Public Law number.

DOE has reviewed and updated this chapter for this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). This chapter summarizes, incorporates by reference, and updates Chapter 11 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 11-1 to 11-25) and presents new information, as applicable, from statutory and other applicable requirements that have arisen since completion of the FEIS. In this chapter:

- Section 11.1 summarizes statutes and regulations that establish DOE's authority to construct and operate a *geologic repository* in the State of Nevada. This section also summarizes the license application statutes and authority for the proposed *Yucca Mountain Repository.*

- Section 11.2 summarizes statutes and regulations that set environmental protection requirements that could apply to the construction and operation of the repository and to transportation of radioactive materials.

- Section 11.3 summarizes potential licenses, permits, and approvals DOE could require to construct and operate the proposed repository.

- Section 11.4 summarizes DOE Orders and describes the mechanism by which these Orders give precedence to NRC rules in relation to the repository.

- Section 11.5 refers to a list of other federal regulations and DOE Orders that are potentially applicable to the construction, operation and monitoring, and closure of a geologic repository.

- Section 11.6 refers to statutes, regulations, requirements, and orders specific to the proposed Nevada rail line.

11.1 Statutes and Regulations that Establish or Affect Authority To Propose, License, and Develop a Geologic Repository

This section describes the DOE analysis of statutes and regulations that establish or affect the Department's authority to construct and operate the proposed Yucca Mountain Repository. It summarizes, incorporates by reference, and updates Section 11.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 11-1 to 11-7).

11.1.1 NUCLEAR WASTE POLICY ACT OF 1982, AS AMENDED (42 U.S.C. 10101 et seq.)

The NWPA establishes the Federal Government's responsibility for the disposal of spent nuclear fuel and high-level radioactive waste and the generators' responsibilities to bear the costs of disposal. Congress amended the original *Nuclear Waste Policy Act of 1982* in 1987 and identified the Yucca Mountain site in Nye County, Nevada, as the only site for study as a potential location for a geologic repository.

Other than appropriations, no changes have been made to the NWPA since completion of the Yucca Mountain FEIS.

11.1.2 YUCCA MOUNTAIN DEVELOPMENT ACT OF 2002 (42 U.S.C. 10135)

On February 15, 2002, President George W. Bush approved the Secretary of Energy's recommendation of Yucca Mountain as the site for the development of a repository for the disposal of spent nuclear fuel and high-level radioactive waste. The House of Representatives approved the Yucca Mountain site on May 8, 2002, as did the Senate on July 9, 2002. The act is a joint resolution of the House of Representatives and the Senate to approve the site at Yucca Mountain, Nevada, for the development of a repository for the disposal of spent nuclear fuel and high-level radioactive waste pursuant to the NWPA. The joint resolution acknowledged that the governor of the State of Nevada submitted a notice of disapproval on April 8, 2002. This approval of the site at Yucca Mountain became known as the *Yucca Mountain Development Act*, which the President signed into law on July 23, 2002.

11.1.3 ENERGY POLICY ACT OF 1992 (42 U.S.C. 13201 et seq.)

Congress passed the *Energy Policy Act of 1992* in part to modify the rulemaking authorities of the U.S. Environmental Protection Agency (EPA) and NRC in relation to the proposed repository at Yucca Mountain. Congress had previously directed EPA to establish standards to protect the general *environment* from offsite releases of radioactive materials in repositories. Section 801(a) of the Energy Policy Act directs EPA (1) to retain the National Academy of Sciences to make findings and recommendations on reasonable public health and safety standards for Yucca Mountain, and (2) to establish Yucca Mountain-specific standards based on and consistent with the National Academy of Sciences findings and recommendations. Section 801(b) of the act directs NRC to modify its technical requirements and criteria for geologic repositories to be consistent with the site-specific EPA Yucca

Mountain standard (40 CFR Part 197). Section 801(c) of the act requires that DOE continue its oversight of the Yucca Mountain site after closure to prevent: (1) unreasonable *risk* of breaching the repository's *barriers*, and (2) increase in the *exposure* of individual members of the public to radiation beyond allowable limits.

11.1.4 DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN A PROPOSED GEOLOGIC REPOSITORY AT YUCCA MOUNTAIN (10 CFR PART 63) AND ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR YUCCA MOUNTAIN (40 CFR PART 197)

In 2001, both EPA and NRC adopted public health and safety standards for any radioactive material to be disposed of in a Yucca Mountain Repository. In 2004, in response to legal challenges, the U.S. Court of Appeals for the District of Columbia Circuit struck down the portions of those standards that addressed the period for which compliance must be demonstrated and remanded the provisions to the federal agencies for revision.

In 2005, EPA proposed new standards to address the court's decision. The proposed standards incorporate multiple compliance criteria applicable at different times for protection of individuals and the environment, and in circumstances involving human intrusion into the repository. The proposals also identify certain specific processes that must be considered in projecting repository performance. When finalized, these standards will be codified in 40 CFR Part 197, Subpart B.

Because Section 801 of the *Energy Policy Act of 1992* requires NRC to modify its technical requirements for licensing of a Yucca Mountain Repository to be consistent with the standards promulgated by EPA, NRC also proposed new standards in 2005 to implement the proposed EPA standards for doses that could occur after 10,000 years but within the period of geologic stability. The proposed NRC standards also specify a value to be used to represent climate change after 10,000 years, as required by EPA, and specify that calculations of radiation doses for workers use the same weighting factors that EPA proposed for calculating individual doses to members of the public. When finalized, these standards will be codified in 10 CFR Part 63.

In developing the Total System Performance Assessment (TSPA)-SEIS model for the analysis in this Repository SEIS, DOE took into consideration the regulatory requirements in the proposed EPA and NRC standards to provide a perspective on potential radiological impacts during the postclosure period. The TSPA-SEIS model for the analyses in this Repository SEIS is in the process of being finalized for purposes of the compliance assessment to be included in the application DOE intends to file with NRC for construction authorization for a Yucca Mountain Repository.

11.1.5 NATIONAL ENVIRONMENTAL POLICY ACT OF 1969 (42 U.S.C. 4321 et seq.)

DOE has prepared this Repository SEIS in accordance with the provisions of the *National Environmental Policy Act*, as amended (NEPA), as implemented by Council on Environmental Quality regulations (40 CFR Parts 1500 through 1508) and DOE NEPA regulations (10 CFR Part 1021), and in conformance with the NWPA.

11.1.6 ATOMIC ENERGY ACT OF 1954, AS AMENDED (42 U.S.C. 2011 et seq.)

The *Atomic Energy Act of 1954, as amended,* provides fundamental jurisdictional authority to DOE and NRC over governmental and commercial use of nuclear materials. This act ensures proper management, production, possession, and use of radioactive materials. To comply with the act, DOE established a system of requirements it issued as DOE Orders. (Section 11.4 discusses DOE Orders.)

The act gives NRC authority to regulate the possession, transfer, storage, and disposal of nuclear materials, as well as aspects of transportation packaging design for radioactive materials that include testing for packaging certification. The act gives EPA the authority to develop standards for the protection of the environment and public health from radioactive material.

11.1.7 FEDERAL LAND POLICY AND MANAGEMENT ACT OF 1976 (43 U.S.C. 1701 et seq.)

The *Federal Land Policy and Management Act of 1976* governs the use of federal lands under the administration of the U.S. Department of the Interior. The analyzed *land withdrawal area* for the proposed repository encompasses public lands under the administration of the Bureau of Land Management, which is an agency of the Department of the Interior. The Bureau governs public lands primarily through the regulations on the establishment of rights-of-way (43 CFR Part 2800) and administrative withdrawals of public domain land from public use (43 CFR Part 2300). The act, by which the government accomplishes most federal land withdrawals, contains a detailed procedure for application, review, and study by the Bureau of Land Management, as well as decisions by the Secretary of the Interior on withdrawal and on the terms and conditions of withdrawal. Only Congress has the power to withdraw federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository.

11.2 Statutes, Regulations, and Executive Orders for Environmental Protection

This section describes the environmental protection statutes, regulations, and executive orders relevant to the proposed Yucca Mountain Repository. It summarizes, incorporates by reference, and updates Section 11.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 11-7 to 11-20).

11.2.1 PROTECTION AND ENHANCEMENT OF ENVIRONMENTAL QUALITY (EXECUTIVE ORDER 11514, AS AMENDED)

Executive Order 11514 directs federal agencies to continuously monitor and control their activities continually to protect and enhance the quality of the environment. The Order also requires the development of procedures both to ensure the fullest practical provision of timely public information and understanding of federal plans and programs with potential environmental impacts, and to obtain the views of interested parties. DOE has promulgated regulations to ensure compliance with NEPA.

11.2.2 AIR QUALITY

11.2.2.1 Clean Air Act of 1963, as Amended (42 U.S.C. 7401 et seq.)

The purpose of the *Clean Air Act of 1963* is to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population."

Pursuant to the act, EPA has established *National Ambient Air Quality Standards* at 40 CFR Parts 50 through 99 to protect the public health and the environment. More specifically, the act regulates emissions of hazardous air pollutants, including radionuclides, through the National Emissions Standards for Hazardous Air Pollutants Program (40 CFR Parts 61 and 63).

11.2.2.2 Nevada Revised Statutes: Air Emission Controls, Chapter 445B

Nevada Revised Statutes, Air Emission Controls, and regulations in the Nevada Administrative Code implement state and federal clean air provisions. DOE would need operating permits from the Nevada Division of Environmental Protection, Bureau of Air Pollution Control, for the control of gaseous and particulate emissions from construction and operation of the proposed repository.

As part of Yucca Mountain *site characterization*, DOE has obtained an *air quality* operating permit from the State of Nevada. The permit placed specific operating conditions on systems that DOE used during site characterization activities. These conditions included limiting the emission of *criteria pollutants*, defining the number of hours per day and per year a system may operate, and determining the testing, monitoring, and recordkeeping required for the system. This operating air quality permit was updated and renewed in 2006 (DIRS 179968-DeBurle 2006).

11.2.3 WATER QUALITY

11.2.3.1 Safe Drinking Water Act of 1974, as Amended [42 U.S.C. 300(f) et seq.]

The primary objective of the *Safe Drinking Water Act* is to protect the quality of public water supplies. This includes any drinking water system at the proposed repository. The act gives EPA the responsibility and authority to regulate public drinking water supplies by establishing drinking water standards, delegating authority for the enforcement of drinking water standards to the states, and protecting *aquifers* from pollution hazards. The Nevada Division of Environmental Protection, Bureau of Safe Drinking Water, is the state agency responsible for the enforcement of drinking water standards. EPA regulations for this program are codified at 40 CFR Part 141, and Nevada rules for this program are codified at Nevada Administrative Code Chapter 445A. Nevada primary drinking water standards are identical to the national standards. The proposed repository would include a drinking water system that would obtain water from a source outside the geologic repository operating area, and DOE would operate the system in accordance with Nevada permitting requirements.

Since completion of the Yucca Mountain FEIS, a standard for natural uranium has gone into effect, but a proposed standard for radon is still pending. EPA implemented the standard for uranium at 0.03 milligrams per liter [40 CFR 141.66(e)]. In addition, EPA lowered the primary drinking water standard for arsenic from 0.05 milligram per liter to 0.01 milligram per liter (40 CFR 141.23).

11.2.3.2 Clean Water Act of 1977 (33 U.S.C. 1251 et seq.)

The purpose of the *Clean Water Act of 1977*, which amended the *Federal Water Pollution Control Act* (Public Law 92-500, Section 2, 86 Stat. 816), is to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." EPA has delegated to the State of Nevada the authority to implement and enforce most programs in the state under the *Clean Water Act of 1977*. An exception is Section 404, which gives the U.S. Army Corps of Engineers permitting authority over activities that discharge dredge or fill material into waters of the United States.

Under the act, the State of Nevada sets water quality standards, and EPA and the state regulate and issue permits for point-source discharges as part of the National Pollutant Discharge Elimination System permitting program. EPA regulations for this program are in 40 CFR Part 122, and Nevada rules for this program are in Nevada Administrative Code Chapter 445A. If the construction or operation of a Yucca Mountain Repository would result in point-source discharges, DOE would obtain a National Pollutant Discharge Elimination System permit from the state.

Sections 401 and 405 of the *Water Quality Act of 1987* added Section 402(p) to the *Clean Water Act of 1977*. Section 402(p) requires EPA to establish regulations for EPA or individual states to issue permits for storm water discharges from industrial activity, which includes construction activities that could disturb 0.2 square kilometer (5 acres) or more (40 CFR Part 122). Nevada rules for this program are in Nevada Administrative Code Chapter 445A.

Under Section 404 of the *Clean Water Act of 1987*, DOE would need to obtain a permit from the U.S. Army Corps of Engineers for discharges of dredge or fill materials into any waters of the United States, which include *wetlands*. For example, DOE has obtained a Section 404 permit for construction activities it might conduct in Coyote Wash and its tributaries. However, in 2006, the Supreme Court (*Rapanos v. U.S.* and *Carabell v. U.S.)* addressed the jurisdictional scope of Section 404 of the *Clean Water Act*, specifically the term "the waters of the U.S." This ruling could affect whether the U.S. Army Corps of Engineers could determine that any dry wash at the Yucca Mountain site is a water of the United States. Appendix C provides further discussion of specific washes at the proposed repository.

Since completion of the Yucca Mountain FEIS, DOE has conducted additional analyses of Section 404 provisions and their impact in relation to the repository and to the Caliente and Mina *rail corridors*. Chapter 4 and Appendix C of this Repository SEIS discuss these analyses.

11.2.3.3 Nevada Revised Statutes: Water Controls, Chapter 445A

Nevada Revised Statutes, Water Controls, classifies the waters of the state, establishes standards for the quality of waters in the state, and specifies permit and notification provisions for storm water discharges and for other discharges to the waters of the state in accordance with provisions of the *Clean Water Act of 1977* (33 U.S.C. 1251 et seq.) and the *Safe Drinking Water Act of 1974* (42 U.S.C. 300 et seq.). These statutes and the regulations in the Nevada Administrative Code set drinking water standards, specifications for certification, and conditions for issuance of variances and exemptions; set standards and requirements for the construction of wells and other water supply systems; establish the different classes of wells and aquifer exemptions; and establish requirements for well operation, monitoring, plugging, and abandonment activities.

The Yucca Mountain FEIS reported that DOE obtained Underground Injection Control and Public Water System permits for site characterization activities at Yucca Mountain. Actually, only one Underground Injection Control Permit was obtained and it covers tracers, pump tests, surface discharges and similar activities. A Public Water System Permit establishes the terms for the provision of potable water.

Since completion of the Yucca Mountain FEIS, DOE has determined that the Nevada Division of Environmental Protection, Bureau of Water Pollution Control, requires a temporary permit for work in waterways of the state. DOE would apply for a temporary permit before using equipment in waters of the state, including dry washes, that could directly discharge pollutants into waterways.

11.2.3.4 Nevada Revised Statutes: Adjudication of Vested Water Rights, Appropriation of Public Waters, Underground Water and Wells, Chapter 534

These Nevada Revised Statutes prescribe requirements for establishing state law water rights for use of public waters of the state, which includes underground waters. These statutes provide procedures for the drilling, construction, and plugging of wells for the extraction of underground water.

DOE filed a water appropriation request with the Office of the Nevada State Engineer on July 22, 1997, for permanent rights to withdraw 430 acre-feet of water annually. These applications were for the five well sites at J-12, J-13, and the C-Wells complex. The use is considered industrial and includes but is not limited to road construction, facility construction, drilling, dust suppression, tunnel and pad construction, testing, culinary and domestic uses, and other uses that relate to the site. These water appropriation permit applications have been denied by the Nevada State Engineer. The U.S. Department of Justice, on behalf of DOE, has appealed this decision in U.S. District Court.

11.2.3.5 Executive Order 11988, Floodplain Management

Executive Order 11988 directs federal agencies to establish procedures to ensure that agencies, for any federal action in a floodplain, consider the potential effects of flood hazards and floodplain management, and to avoid floodplain impacts where possible. DOE implementing regulations are in 10 CFR Part 1022.

11.2.3.6 Compliance with Floodplain/Wetlands Review Requirements (10 CFR Part 1022)

The Yucca Mountain FEIS discussed compliance with floodplain and wetland review requirements. These federal regulations establish DOE procedures for identification of proposed actions in floodplains and provide for early public review of the proposed actions. If DOE determines that an action it proposes would take place wholly or partly in a floodplain or wetland, the regulation requires preparation of a floodplain or wetland assessment with a project description and a discussion of project impacts, alternatives, and mitigations. If there is no practicable alternative to impacts to and within a floodplain or wetland, DOE must design or modify its action to minimize potential harm.

Appendix C of this Repository SEIS contains a floodplain and wetlands assessment that examines the effects of proposed repository construction and operation.

11.2.4 HAZARDOUS MATERIALS PACKAGING, TRANSPORTATION, AND STORAGE

11.2.4.1 Roles of the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission in Regulation of the Transportation of Radioactive Materials

As the Yucca Mountain FEIS described, NRC and the U.S. Department of Transportation share primary responsibility for regulation of the safe transportation of radioactive materials in the United States. The Department of Transportation has the responsibility to develop and implement transportation safety standards for hazardous materials, including radioactive materials. Title 49 of the Code of Federal Regulations establishes Department of Transportation standards and requirements for packaging, transporting, and handling radioactive materials for all modes of transportation. These standards address labeling, shipping papers, placarding, loading and unloading, allowable radiation levels, and limits for contamination of packages and vehicles, among other requirements. The regulations specify safety requirements for vehicles and transportation operations, training for personnel who perform handling and transportation of hazardous materials, and liability insurance requirements for carriers.

NRC sets performance standards for transportation packaging (*shipping casks*) for materials with higher levels of *radioactivity*. The U.S. Department of Transportation, by agreement with NRC, accepts the standards of 10 CFR Part 71 for packaging. NRC also establishes safeguards and security regulations to minimize the possibility of theft, diversion, or attack on shipments of radioactive materials (10 CFR Part 73). NRC revised Class 7 (radioactive materials) requirements on October 1, 2004, to align with the International Atomic Energy Agency regulations for the safe transport of radioactive materials. NRC coordinated the final rule with the Department of Transportation to ensure that consistency between NRC and Department of Transportation regulations (69 FR 58841).

The shipment of spent nuclear fuel and high-level radioactive waste is highly regulated and subject to the utmost scrutiny. DOE carefully follows U.S. Department of Transportation and NRC transportation rules now and will follow or exceed any others that might be established in the future, whether by Congress, the Department of Transportation, or NRC.

11.2.4.2 Hazardous Materials Transportation Act (49 U.S.C. 1801 et seq.)

The *Hazardous Materials Transportation Act* gives the U.S. Department of Transportation the authority to regulate the transport of hazardous materials, including the radioactive materials that DOE would transport to the proposed Yucca Mountain Repository from 72 commercial and 4 DOE sites. Department of Transportation regulations (49 CFR Parts 171 through 180) require the identification of hazardous materials that DOE would transport to Yucca Mountain. The rules for selection of routes that carriers must use to transport such materials, and guidance to states in the designation of preferred routes, are in 49 CFR Part 397.

11.2.4.3 Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. 1001 et seq.)

The Yucca Mountain FEIS described Subtitle A of the *Emergency Planning and Community Right-to-Know Act of 1986* (also known as "SARA Title III"). Federal facilities, which would include a repository at Yucca Mountain, must provide information on hazardous and toxic chemicals to state emergency response commissions, local emergency planning committees, and EPA. The goal of providing this information is to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. The required information includes inventories of specific chemicals used or stored and descriptions of releases that occur from sites.

11.2.4.4 Nevada Revised Statutes: State Fire Marshal, Chapter 477 and Hazardous Materials, Chapter 459

The State of Nevada could require a Hazardous Materials Storage Permit for DOE to store hazardous materials in quantities above those the Uniform Fire Code specifies (Nevada Revised Statutes, Chapter 477). To receive such a permit, if necessary, DOE would submit an application to the Nevada State Fire Marshal that described its plans for the storage of hazardous materials in excess of specified quantities. DOE obtained a permit from the State Fire Marshal for the storage of flammable materials during site characterization activities. This permit is still active. In addition, DOE would be required to manage and dispose of hazardous waste pursuant to Nevada Revised Statutes Chapter 459 – Hazardous Materials.

11.2.4.5 U.S. Nuclear Regulatory Commission Radioactive Materials Packaging and Transportation Regulations (10 CFR Parts 71 and 73)

Under 10 CFR Part 71, NRC regulates the packaging and transport of spent nuclear fuel for its licensees, which include commercial shippers of radioactive material. In addition, under an agreement with the U.S. Department of Transportation, NRC sets the standards for packages containing Type B quantities of radioactive materials, which include spent nuclear fuel and high-level radioactive waste. An applicant provides the results of its analyses and tests to NRC in a Safety Analysis Report for Packaging. On approving the report, NRC issues a Certificate of Compliance. Under the NWPA, DOE is required to use NRC-certified casks for shipment of spent nuclear fuel or high-level radioactive waste to the repository.

The regulations at 10 CFR Part 73 govern safeguards and physical security during the shipment of spent nuclear fuel. These regulations specify requirements for vehicles, carrier personnel, communications, notification of state governors, escorts, and route planning for such shipments.

The shipment of spent nuclear fuel and high-level radioactive waste is highly regulated and subject to the utmost scrutiny. DOE carefully follows U.S. Department of Transportation and NRC transportation rules now and will follow or exceed any others that might be established in the future, whether by Congress, the Department of Transportation, or NRC.

11.2.4.6 U.S. Department of Transportation Hazardous Materials Packaging and Transportation Regulations (49 CFR Subchapter C – Hazardous Materials Regulations, Parts 171 through 180)

The U.S. Department of Transportation regulates the shipment of hazardous materials, which include spent nuclear fuel and high-level radioactive waste, by land, air, and navigable water. As outlined in a 1979 memorandum of understanding with NRC (44 FR 38690, July 2, 1979), the Department of Transportation specifically regulates carriers of spent nuclear fuel and the conditions of transport, such as routing for highway shipments, handling and storage, and vehicle and driver requirements. The Department of Transportation does not regulate the routing of rail shipments of radioactive materials.

The purposes of the public highway routing regulations of the U.S. Department of Transportation are to reduce the impacts of the transportation of *Highway Route Controlled Quantities of Radioactive Materials* [49 CFR 173.403(1)], to establish consistent and uniform requirements for route selection, and to identify the roles of state and local governments in the routing.

U.S. Department of Transportation regulations include requirements for carriers, drivers, vehicles, routing, packaging, labeling, marking, placarding, shipping papers, training, and emergency response. The requirements specify the maximum dose rate external to the packaging and the maximum allowable levels of radioactive surface contamination on packages and vehicles.

The shipment of spent nuclear fuel and high-level radioactive waste is highly regulated and subject to the utmost scrutiny. DOE carefully follows U.S. Department of Transportation and NRC transportation rules now and will follow or exceed any others that might be established in the future, whether by Congress, the Department of Transportation, or NRC.

11.2.5 CONTROL OF POLLUTION

11.2.5.1 Pollution Prevention Act of 1990 (42 U.S.C. 13101 et seq.)

The *Pollution Prevention Act of 1990* establishes a national policy for waste management and pollution control that focuses first on source reduction, then on environmentally safe recycling, treatment, and disposal. DOE requires each of its sites to establish specific goals to reduce the generation of waste.

11.2.5.2 Standards for Protection Against Radiation (10 CFR Part 20)

The purpose of these standards is to provide standards and procedures for protection against radiation from NRC-licensed activities. Provisions of 10 CFR Part 20 address repository occupational dose limits, public dose limits, survey and monitoring procedures, exposure control in *restricted areas*, respiratory protection and controls, precautionary procedures, and related topics.

11.2.5.3 DOE Worker Safety and Health Program (10 CFR Part 851)

The purpose of these regulations, which became effective on May 25, 2007, is to ensure that DOE contractor workplaces are free from recognized hazards that can cause death or serious physical harm. To accomplish this objective, 10 CFR Part 851 establishes management responsibilities, worker rights, safety and health standards, and required training. Contractors include parent corporations and subcontractors that have responsibilities for work at a DOE site in furtherance of a DOE mission. The contractor must provide DOE with a worker and safety health program that describes the methods it will use to implement the requirements. DOE must review and approve these programs. For example, this regulation prohibits a DOE contractor from performing work at a covered workplace unless an approved worker and safety health program is in place.

11.2.5.4 Low-Level Radioactive Waste Policy Amendments Act of 1985 (42 U.S.C. 2021b through 2021j)

Under the *Low-Level Radioactive Waste Policy Amendments Act of 1985*, DOE is responsible for the disposal of any *low-level radioactive waste* that operations at the proposed Yucca Mountain could generate. DOE would control and dispose of site-generated low-level radioactive waste in a DOE low-level waste disposal site, a site in an *Agreement State*, or in a NRC-licensed site.

In addition, this act assigns responsibility for disposal of greater-than-class-C low-level radioactive waste to the Federal government.

11.2.5.5 Resource Conservation and Recovery Act, as Amended (42 U.S.C. 6901 et seq.)

EPA regulates the treatment, storage, and disposal of hazardous and nonhazardous waste in accordance with the provisions of the *Solid Waste Disposal Act*, as amended by the *Resource Conservation and Recovery Act* and the *Hazardous and Solid Waste Amendments Act of 1984*, and applicable state laws.

EPA regulations that implement the *hazardous waste* portions of the *Resource Conservation and Recovery Act* define hazardous wastes and specify requirements for their transportation, handling, treatment, storage, and disposal (40 CFR Parts 260 through 272).

Subtitle C of the act requires characterization and management of covered hazardous wastes. DOE could generate hazardous waste during repository operations. It would track the amount of hazardous wastes each month (to determine generator status) during construction and operation. Sections 444.850 to 444.8746 of the Nevada Administrative Code are the corresponding requirements for wastes that EPA regulates under Subtitle C.

11.2.5.6 Noise Control Act of 1972 (42 U.S.C. 4901 et seq.)

Section 4 of the *Noise Control Act of 1972* directs federal agencies to carry out programs in their jurisdictions “to the fullest extent within their authority” and in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare. This law provides requirements for control of noise from construction, operation, or closure activities at Yucca Mountain.

11.2.5.7 Nevada Revised Statutes: Sanitation, Chapter 444

These statutes and their matching regulations in the Nevada Administrative Code establish the standards, permits, and requirements for septic tanks and other sewage disposal systems for single-family dwellings, communities, and commercial buildings. The construction and operation of a sanitary sewage collection system at Yucca Mountain requires a permit from the Nevada Division of Environmental Protection. Since completion of the Yucca Mountain FEIS, Nevada has clarified that applicants must submit plans and specifications to the Division for approval.

These statutes and regulations set forth the definitions, methods of disposal, and special requirements for *solid waste* collection and transportation standards, as well as classification of landfills. DOE operates a permitted large-capacity septic system at the Yucca Mountain site under these provisions. This general permit to operate and discharge from a large-capacity septic system expires on July 22, 2009.

EPA has authorized the State of Nevada to regulate the management and disposal of solid, hazardous, and mixed wastes in the state. The Nevada Division of Environmental Protection or an equivalent solid waste management authority would regulate the on- and offsite disposal of nonhazardous solid wastes from the proposed repository.

11.2.5.8 Executive Order 12088, Federal Compliance with Pollution Control Standards

Executive Order 12088, as amended by Executive Order 12580, Superfund Implementation Control Standards, generally directs federal agencies to comply with applicable administrative and procedural pollution control standards of, but not limited to, the *Clean Air Act*, the *Noise Control Act*, the *Clean Water Act*, the *Safe Drinking Water Act*, the *Toxic Substances Control Act*, and the *Resource Conservation and Recovery Act*. DOE must comply with this order for a range of activities for the proposed repository.

11.2.5.9 Executive Order 12856, Right-To-Know Law and Pollution Prevention Requirements

Executive Order 12856 directs federal agencies to reduce and report toxic chemicals that enter any waste stream; improve emergency planning, response, and *accident* notification; and encourage the use of clean technologies and testing of innovative prevention technologies. In addition, the Executive Order states that federal agencies are persons for purposes of the *Emergency Planning and Community Right-to-Know Act* (SARA Title III), which requires agencies to meet the requirements of the act. DOE must comply with these orders, as applicable, for a range of DOE activities for the proposed repository.

11.2.6 CULTURAL RESOURCES

11.2.6.1 National Historic Preservation Act, as Amended (16 U.S.C. 470 et seq.)

The *National Historic Preservation Act* provides for the placement of sites with significant national historic value on the *National Register of Historic Places*. The act requires no permits or certifications.

11.2.6.2 Archaeological Resources Protection Act, as Amended (16 U.S.C. 470aa et seq.)

The *Archaeological Resources Protection Act* requires a permit for the excavation or removal of archaeological resources from publicly held or American Indian lands. Excavations must further archaeological knowledge in the public interest, and the removed resources are to remain the property of the United States. If a resource is discovered on land that an American Indian tribe owns, the tribe must give its consent before a permit is issued, and the permit must contain terms or conditions the tribe requests.

11.2.6.3 American Indian Religious Freedom Act of 1978 (42 U.S.C. 1996)

The *American Indian Religious Freedom Act of 1978* reaffirms American Indian religious freedom under the First Amendment and establishes the policy to protect and preserve the inherent and constitutional right of American Indians to believe, express, and exercise their traditional religions. This law ensures the protection of sacred locations and access of American Indians to those sacred locations and traditional resources that are integral to the practice of their religions.

11.2.6.4 Native American Graves Protection and Repatriation Act of 1990 (25 U.S.C. 3001)

The *Native American Graves Protection and Repatriation Act of 1990* directs the Secretary of the Interior to guide the repatriation of federal archaeological collections and collections that are culturally affiliated with American Indian tribes and held by museums that receive federal funding. Major provisions of this law include (1) the establishment of a review committee with monitoring and policymaking responsibilities, (2) the development of regulations for repatriation that include procedures for the identification of lineal descent or cultural affiliation needed for claims, (3) the oversight of museum programs for meeting the inventory requirements and deadlines of this law, and (4) the development of procedures to handle unexpected discoveries of graves or grave artifacts during activities on federal or tribal land. Certain provisions of this act would govern DOE if any surveys or excavations under the Proposed Action led to discoveries of American Indian graves or grave artifacts.

11.2.6.5 Antiquities Act (16 U.S.C. 431 et seq.)

The *Antiquities Act* protects historic and prehistoric ruins, monuments, and objects of antiquity (including paleontological resources) on federally owned or controlled lands. If DOE found historic or prehistoric ruins or objects during the construction or operation of proposed repository facilities, it would have to determine if adverse effects to these ruins or objects would occur. If adverse effects would occur, the Secretary of the Interior would have to grant permission to proceed with the activity (36 CFR Part 296 and 43 CFR Parts 3 and 7).

11.2.6.6 Executive Order 13007, Indian Sacred Sites

Executive Order 13007 directs federal agencies, to the extent permitted by law and not inconsistent with agency missions, to avoid adverse effects to sacred sites and to provide access to those sites to American Indians for religious practices. The Executive Order directs agencies to plan projects to provide protection of and access to sacred sites to the extent compatible with the project.

11.2.6.7 Executive Order 13175, Consultation and Coordination with Indian Tribal Governments

Executive Order 13175 directs federal agencies to establish regular and meaningful consultation and collaboration with American Indian tribal governments in the development of federal policies that have tribal implications, to strengthen United States government-to-government relationships with tribes, and to reduce the imposition of unfunded mandates on tribal governments.

11.2.7 ENVIRONMENTAL JUSTICE

11.2.7.1 Executive Order 12898, Environmental Justice

Executive Order 12898 directs federal agencies, to the extent practicable, to make the achievement of environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on *minority* and *low-income populations* in the United States and its territories and possessions. The order provides that the federal agency responsibilities it establishes are to apply equally to American Indian programs.

11.2.8 ECOLOGY AND HABITAT

11.2.8.1 Endangered Species Act, as Amended (16 U.S.C. 1531 et seq.)

The *Endangered Species Act* provides a program for the conservation of threatened and endangered species and the ecosystems on which those species rely. If a proposed action of a federal agency could affect threatened or endangered species or their habitat, the federal agency must assess the potential impacts and develop measures to minimize those impacts. The agency then must consult formally with the U.S. Fish and Wildlife Service (part of the Department of the Interior) and the National Marine Fisheries Service (part of the Department of Commerce), as required under Section 7 of the act. The regulations that implement the act are in 50 CFR Parts 15 and 402.

11.2.8.2 Fish and Wildlife Coordination Act, as Amended (16 U.S.C. 661, 48 Stat. 401)

The *Fish and Wildlife Coordination Act* promotes more effectual planning and cooperation among federal, state, public, and private agencies for the conservation and rehabilitation of the nation's fish and wildlife and authorizes the Department of the Interior to provide assistance.

11.2.8.3 Migratory Bird Treaty Act, as Amended (16 U.S.C. 703 et seq.)

The purpose of the *Migratory Bird Treaty Act* is to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. The act regulates the take and harvest of migratory birds.

11.2.8.4 Bald and Golden Eagle Protection Act, as Amended (16 U.S.C. 668 through 668d)

The *Bald and Golden Eagle Protection Act* makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States (Sections 668 and 668c). The Department of the Interior regulates activities that might adversely affect bald and golden eagles.

11.2.8.5 Nevada Revised Statutes: Protection and Preservation of Timbered Lands, Trees, and Flora, Chapter 527

These provisions of the Nevada Revised Statutes broadly protect the indigenous flora of the State of Nevada. On determination that a species or subspecies of native flora is threatened with extinction, the state places that species or subspecies on its list of fully protected species. In general, no member of the species or subspecies may be taken or destroyed unless an authorized state official issues a special permit.

11.2.8.6 Nevada Revised Statutes: Hunting, Fishing, and Trapping; Miscellaneous Protective Measures, Chapter 503

These statutes and the provisions in Nevada Administrative Code, Chapter 503, Sections 010 through 104, specify procedures for the classification and protection of wildlife. On determination that an animal species is threatened with extinction, the state places the species on its list of fully protected species. In general, no member of the species may be taken or destroyed unless the Nevada Division of Wildlife issues a special permit.

11.2.8.7 Executive Order 11990, Protection of Wetlands

Executive Order 11990 directs federal agencies to avoid new construction in wetlands unless there is no practicable alternative and unless the proposed action includes all practicable measures to minimize harm to wetlands that might result from such use. DOE requirements for compliance with wetlands activity review procedures are in 10 CFR Part 1022 (Section 11.2.2.6).

11.2.8.8 Executive Order 13112, Invasive Species

Executive Order 13112 directs federal agencies to act to prevent the introduction of or to monitor and control invasive (nonnative) species, provide for restoration of native species, conduct research, promote educational activities, and exercise care in taking actions that could promote the introduction or spread of invasive species.

11.2.8.9 Executive Order 13186, Responsibilities of Federal Agencies To Protect Migratory Birds

Executive Order 13186 requires federal agencies to avoid or minimize the negative impacts of their actions on migratory birds and to take active steps to protect birds and their habitats. The order directs each federal agency that takes actions that have or are likely to have a negative impact on migratory bird populations to work with the Fish and Wildlife Service to develop an agreement to conserve those birds. The order requires environmental analyses of federal actions to evaluate effects of those actions on migratory birds, to control the spread and establishment in the wild of exotic animals and plants that could harm migratory birds and their habitats, and either to provide advance notice of actions that could result in the take of migratory birds or report annually to the Fish and Wildlife Service on the numbers of each species taken during the conduct of agency actions.

11.2.9 USE OF LAND AND WATER BODIES

11.2.9.1 Coastal Zone Management Act (16 U.S.C. 1451 et seq.)

The purpose of the *Coastal Zone Management Act* is to preserve, protect, develop, restore, and enhance the resources of the nation’s coastal zones. Resources include wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat. This law provides for (1) management to minimize the loss of life and property from improper development and destruction of natural protective features such as beaches, dunes, wetlands, and barrier islands; and (2) improvement, safeguarding, and restoration of the quality of coastal waters, and for protection of existing uses of those waters. The act requires priority consideration to coastal-dependent uses and orderly processes for siting major facilities in relation to national defense, energy, fisheries development, recreation, ports and transportation, and the location of new commercial and industrial developments in or adjacent to areas where such development already exists.

Transportation of spent nuclear fuel to a repository at Yucca Mountain could require the use of barges for transportation along portions of routes from some storage facilities. In addition, rail *corridors*, roads, and bridges from some storage facilities could require repair or enhancement before they could support shipment of spent nuclear fuel. The regulations that implement the act are in 15 CFR Part 930.

11.2.9.2 Rivers and Harbors Act (33 U.S.C. 401 et seq.)

The transportation of spent nuclear fuel and high-level radioactive waste could require the construction or modification of road or rail bridges that span navigable waters. The *Rivers and Harbors Act* prevents the alteration or modification of the course, location, condition, or capacity of any channel of any navigable water of the United States without a permit from the Army Corps of Engineers. If DOE required construction of a road or rail bridge that would span navigable waters, it would need to obtain a permit from the Corps. Regulations that implement this act are in 33 CFR Part 323.

11.2.9.3 Materials Act of 1947 (30 U.S.C. 601 through 603)

The *Materials Act of 1947* authorizes land management agencies, such as the Bureau of Land Management, to make common varieties of sand, stone, and gravel from public lands available to federal and state agencies under free-use permits. The Bureau of Land Management regulations that implement the act are in 43 CFR Part 3604.

11.2.9.4 Farmland Protection Policy Act (7 U.S.C. 4201 et seq.)

The *Farmland Protection Policy Act* seeks to minimize the extent to which federal programs contribute to the unnecessary and irreversible conversion of farmlands to nonagricultural uses. Compliance with this law requires concurrence from the Natural Resources Conservation Service of the Department of Agriculture that proposed activities would not affect farmlands. Regulations that implement the act are in 7 CFR Part 658.

11.2.10 HOMELAND SECURITY

11.2.10.1 Energy Policy Act of 2005 (42 U.S.C. 15801)

Subtitle D (Nuclear Security) of the *Energy Policy Act of 2005* requires that NRC establish a system to secure the transfer of nuclear materials, which include spent nuclear fuel and high-level radioactive waste. Subtitle E (Nuclear Energy) directs DOE to conduct research on cost-effective technologies for increasing (1) the safety of nuclear facilities from natural phenomena and (2) the security of nuclear facilities from deliberate attacks.

11.2.10.2 Homeland Security Act of 2002 (6 U.S.C. 101 et seq.)

The *Homeland Security Act of 2002* contains requirements for safekeeping of radioactive materials. Specifically, the act provides for measures to secure the people, *infrastructures*, property, resources, and systems in the United States from acts of terrorism that involve chemical, biological, radiological, or nuclear weapons or other emerging threats.

11.3 Potential Permits, Licenses, and Approvals

Table 11-1 lists potential permits, licenses, and approvals that DOE could need for construction, operation and monitoring, and closure of a Yucca Mountain Repository as well as permits and approvals that could be necessary for the construction and operation of a railroad in Nevada.

Table 11-1. Permits, licenses, and approvals for the proposed Yucca Mountain Repository in Nevada.

Activity	Regulatory action	Statute or regulation	Agency(ies)
Disposal of spent nuclear fuel and high-level radioactive waste	Final public health and environmental protection standards	40 CFR Part 197	EPA
Repository construction, operation, and closure	Construction authorization; license to receive and possess source, special nuclear, and byproduct material	10 CFR Part 63	NRC
Repository construction, operation, and closure	Withdrawal of land from public use	Future Congressional bill needed to authorize withdrawal	Congress, BLM
Air emissions	Approvals for new sources of *toxic air pollutants*	40 CFR Parts 61 and 63, NAC 445B	NDEP
Air emissions	Air quality operating permit	40 CFR Parts 61 and 63, NAC 445B	NDEP
Air emissions	National emissions standards for hazardous air pollutants Subpart H (*radionuclides*)	40 CFR Part 61	EPA
Air emissions	Standards for protection against *radiation*	10 CFR Part 20	NRC
Drinking water	Public water system permit	NAC 445A	NDEP
Effluents	Storm water discharge	40 CFR Part 122, NAC 445A	NDEP
Effluents	National Pollutant Discharge Elimination System	40 CFR Part 122, NAC 445A	NDEP
Effluents	Septic system permit	NAC 444 and 445A	NDEP
Effluents	Underground injection control permit	40 CFR Part 144, NAC 445A	NDEP
Excavation; facility construction	Cultural resources review clearance, Section 106	36 CFR Part 800	Advisory Council on Historic Preservation, State Historic Preservation Office
Excavation; facility construction	Permit to proceed (Objects of Antiquity)	36 CFR Part 296, 43 CFR Parts 3 and 7	DOI
Excavation; facility construction	Permit for excavation or removal of archaeological resources	16 U.S.C. 470 et seq.	DOI, affected American Indian tribes
Facility construction	Free use of mineral materials	43 CFR Part 3604	BLM
Facility construction	Permit for discharge of dredged or fill materials to waters of the United States	*Clean Water Act*, Section 404	U.S. Army Corps of Engineers
TAD canister certification	Requirements for TAD canisters	10 CFR Parts 63, 71, 72	NRC

Table 11-1. Permits, licenses, and approvals for the proposed Yucca Mountain Repository in Nevada (continued).

Activity	Regulatory action	Statute or regulation	Agency(ies)
Transportation casks	Certification of transportation casks	10 CFR Part 71	NRC
Facility construction and operation	*Threatened and endangered species* consultation	50 CFR 402	Fish and Wildlife Service
Materials storage	Hazardous materials storage permit	NAC 459 and 477	Nevada State Fire Marshal
Water appropriations	Water appropriation permit	Nevada Revised Statutes 532, 533 and 534	Nevada State Engineer

Source: DIRS 155970-DOE 2002, p. 11-2.

BLM = Bureau of Land Management.
CFR = Code of Federal Regulations.
EPA = U.S. Environmental Protection Agency.
DOI = U.S. Department of the Interior.
NAC = Nevada Administrative Code.
NDEP = Nevada Division of Environmental Protection.
NRC = U.S. Nuclear Regulatory Commission.
TAD = transportation, aging, and disposal (canister).
U.S.C. = United States Code.

11.4 Department of Energy Orders

This section summarizes, incorporates by reference, and updates Section 11.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 11-20 to 11-22).

In the Yucca Mountain FEIS, Table 11-3 listed DOE Orders potentially relevant to the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain (DIRS 155970-DOE 2002, pp. 11-21 to 11-22). Some DOE Orders overlap or duplicate NRC repository licensing regulations in whole or in part. Recognizing this, DOE issued DOE HQ Order 250.1, *Civilian Radioactive Waste Management Facilities - Exemption from Departmental Directives*. This order exempts geologic repository design, construction, operation, and *decommissioning* from compliance with the provisions of DOE Orders that overlap or duplicate NRC requirements in relation to radiation protection, nuclear safety (including quality assurance), and the safeguards and security of nuclear material. The exemption would apply only to the portions of the Proposed Action for which DOE sought an NRC license. DOE Orders would continue to establish requirements for other repository activities that would fall outside the scope of this exemption, such as computer security (DOE Order 205.1A). The mechanism by which DOE Orders give precedence to NRC rules has not changed since completion of the Yucca Mountain FEIS.

Table 11-2 lists DOE Orders potentially relevant to the construction, operation, and closure of the proposed Yucca Mountain Repository that have been issued since the completion of the Yucca Mountain FEIS. Table 11-3 updates the revised numbering of relevant DOE Orders in Table 11-3 of the Yucca Mountain FEIS.

Table 11-2. Relevant DOE Orders issued since completion of the Yucca Mountain FEIS.

New DOE Order, date issued, and title	Description
414.1-2A (06/17/2005) Quality Assurance Management System Guide	Provides information on principles and practices to establish and implement an effective quality assurance program or quality management system according to the requirements of 10 CFR Part 830.
414.1-5 (03/02/2006) Corrective Action Program Guide	Provides guidance to DOE organizations and contractors in the development, implementation, and follow-up of corrective action programs using the feedback and improvement core safety function in DOE's Integrated Safety Management System.
420.1B (12/22/2005) Facility Safety	Establishes facility and programmatic safety requirements for DOE facilities, which include nuclear and explosives safety design criteria, fire protection, criticality safety, natural phenomena hazards mitigation, and the System Engineer Program.
426.1-1A (05/18/2004) Federal Technical Capability Manual	Provides requirements and responsibilities to ensure recruitment and hiring of technically capable personnel to retain critical technical capabilities within DOE at all times.
440.1B (05/17/2007) DOE Worker Protection Program	Establishes the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE workers with a safe and healthful workplace.
231.1A (06/30/2004) Environment, Safety and Health Reporting	Ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed to ensure that DOE is fully informed on a timely basis about events that could adversely affect the health and safety of the public, workers, and the environment.
414.C (6/17/2005) Quality Assurance	To ensure that DOE products and services meet or exceed customer expectations. The order requires each DOE organization to develop and implement a quality assurance program.
433.1A (02/13/2007) Maintenance Management Program for DOE Nuclear Facilities	Defines the safety management program required by 10 CFR 830.204(b)(5) for maintenance and the reliable performance of structures, systems, and components that are part of the safety basis required by 10 CFR 830.202.1 at hazard Category 1, 2, and 3 DOE nuclear facilities.
450.1 (01/15/2003) Environmental Protection Program	Implements sound stewardship practices that are protective of air, water, land, and other natural and cultural resources that DOE operations affect and by which DOE cost-effectively complies with applicable environmental; public health; and resource protection laws, regulations, and Departmental requirements.
451.1 (10/06/2006) National Environmental Policy Act Compliance Program	Establishes DOE internal requirements and responsibilities for implementing the *National Environmental Policy Act*. Describes procedures to ensure timely public information and the understanding of federal plans and programs with potential environmental impacts, and to obtain the views of interested parties. DOE updated Order 451.1 on October 6, 2006, to reflect departmental reorganization.
452.2C (6/12/2006) Nuclear Explosive Safety	Establishes specific nuclear explosive safety program requirements to implement the DOE standards and other nuclear explosive safety criteria for routine and planned nuclear explosive operations.

Table 11-2. Relevant DOE Orders issued since completion of the Yucca Mountain FEIS (continued).

New DOE Order, date issued, and title	Description
460.2A (12/22/2004) Departmental Materials Transportation and Packaging Management	Establishes requirements and responsibilities for management of DOE, including the National Nuclear Security Administration, materials transportation, and packaging to ensure the safe, secure, efficient packaging and transportation of materials, both hazardous and nonhazardous.
226.1 (9/15/2005) Implementation of Department of Energy Oversight Policy	Provides direction for implementing DOE Policy P 226.1, Department of Energy Oversight Policy (06-10-2005), which establishes DOE policy for assurance systems and processes established by DOE contractors and oversight programs performed by DOE line management and independent oversight organizations.
460.1B (04/04/2003) Packaging and Transportation Safety	Establishes safety requirements for the proper packaging and transportation of DOE/National Nuclear Security Administration offsite shipments and onsite transfers of hazardous materials, and for modal transport.
461.1A (04/26/2004) Packaging and Transfer or Transportation of Materials of National Security Interest	Establishes requirements and responsibilities for offsite shipments of naval nuclear fuel elements, Category I and Category II special nuclear material, nuclear explosives, nuclear components, special assemblies, and other materials of national security interest.
470.2B (10/31/2002) Independent Oversight And Performance Assurance Program	The Independent Oversight Program is designed to enhance the DOE safeguards and security; cyber security; emergency management; and environment, safety, and health programs by providing DOE with an independent evaluation of the adequacy of DOE policy and the effectiveness of line management performance in safeguards and security; cyber security; emergency management; environment, safety, and health.

CFR = Code of Federal Regulations.
DOE = U.S. Department of Energy.
FEIS = Yucca Mountain Final Environmental Impact Statement.

11.5 Other Potentially Applicable Federal Regulations

This section incorporates by reference Table 11-4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. 11-23 to 11-25). That table listed federal regulations and DOE Orders potentially applicable to the construction, operation and monitoring, and closure of a geologic repository.

11.6 Statutes, Regulations, Requirements, and Orders Specific to the Proposed Nevada Rail Line

Based on its obligations under the NWPA and its decision to select the mostly rail scenario for the transportation of spent nuclear fuel and high-level radioactive waste (69 FR 18557; April 8, 2004), DOE would ship spent nuclear fuel and high-level radioactive waste by rail in Nevada. To meet this need, DOE is proposing to construct and operate a railroad to connect the repository to an existing rail line in Nevada. Many of the statutes and regulations in the preceding sections of Chapter 11 are applicable to both the repository and the railroad. Chapter 6 of the Rail Alignment EIS discusses the potentially applicable requirements.

Table 11-3. Revised DOE Orders since completion of the Yucca Mountain FEIS.

Previous number and title		Revised number and title	
1300.2A	Department of Energy Technical Standards Program	252.1	Technical Standards Program
425.1	Facility Startup and Restart	425.1C	Startup and Restart of Nuclear Facilities
151.1	Comprehensive Emergency Management System	151.C	Comprehensive Emergency Management System
1360.2B	Unclassified Computer Security Program	205.1A	Department of Energy Cyber Security Management
3790.1B	Federal Employee Occupational Safety and Health Program	440.1B	Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees
5400.1	General Environmental Protection Program	231.1A Chg. 1	Environment, Safety and Health Reporting
5400.5	Radiation Protection of the Public and the Environment	231.1A Chg. 1	Environment, Safety and Health Reporting
5484.1	Environmental Protection, Safety, and Health Protection Information Reporting Requirements	231.1A Chg. 1	Environment, Safety and Health Reporting
5610.14	Transportation Safeguards System Program Operations	461.1A	Packaging and Transfer or Transportation of Nuclear Materials of National Security Interest
5632.1C	Protection and Control of Safeguards and Security Interests	470.4A	Safeguards and Security Program

Chg = Change.
DOE = U.S. Department of Energy.
FEIS = Yucca Mountain Final Environmental Impact Statement.

REFERENCES

179968 DeBurle 2006 DeBurle, M.A. 2006. "Re: Class II General Air Quality Operation Permit Renewal, #AP9199-0573.02, FIN #A0023." Letter from M.A. DeBurle (NDEP) to W.J. Arthur, III (DOE/OCRWM), August 8, 2006, 0814065554, MAD/tu, with enclosure. ACC: MOL.20070316.0087.

155970 DOE 2002 DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; MOL.20020524.0315; MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319; MOL.20020524.0320.

12

Glossary

12. GLOSSARY

The U.S. Department of Energy (DOE or the Department) has provided this glossary to assist readers in the interpretation of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). The Glossary includes definitions of technical and regulatory terms common to DOE *National Environmental Policy Act* (NEPA) documents and explains these terms with their most likely meanings in the context of DOE NEPA documents, and in particular this Repository SEIS. To better aid the reader, a number of terms in this glossary emphasize their project-specific relationship to the Yucca Mountain Repository (*italicized* words are defined in the glossary). DOE derived the definitions in this glossary from the most authoritative sources available (for example, a statute, regulation, DOE directive, dictionary, or technical reference book) and checked each definition against other authorities.

100-year flood	A flood event of such magnitude that it occurs, on average, every 100 years; this equates to a 1-percent chance of its occurring in a given year. A base flood may also be referred to as a 100-year storm. The area inundated during the base flood is sometimes called the 100-year *floodplain*.
accessible environment	For this *Repository* SEIS, all points on Earth outside the surface and *subsurface* area controlled over the long term for the proposed *repository*, including the atmosphere above the *controlled area*.
accident	An unplanned sequence of events that results in undesirable consequences. Examples in this *Repository* SEIS include an inadvertent release of *radioactive* or hazardous materials from their containers or *confinement* to the *environment*; vehicular accidents during the transportation of highly radioactive materials; and industrial accidents that could affect workers in the facilities.
actinide	Any one of a series of chemically similar elements of *atomic numbers* 89 (actinium) through 103 (lawrencium). All actinides are *radioactive*.
affected environment	The physical, biological, and human-related environment that is sensitive to changes resulting from the Proposed Action. The extent of the affected environment may not be the same for all potentially affected resource areas. For example, traffic may increase within four miles of a hypothetical site from which waste would be removed to a nearby landfill (the extent of the affected environment with respect to transportation impacts). In contrast, groundwater extending two miles from the hypothetical site may be affected (the extent of the affected environment with respect to groundwater impacts).
aging	The retention of *commercial spent nuclear fuel* on the surface in dry storage for the purpose of reducing its thermal output as necessary to meet repository thermal management goals.
aging pads	Provide the capability to age commercial *spent nuclear fuel* as necessary to meet *waste package* thermal limits.

aging overpack	A *cask* specifically designed for aging *spent nuclear fuel*. TAD canisters and *dual-purpose canisters* would be placed in aging overpacks for aging on the *aging pad*.
Agreement State	A state that reaches an agreement with the NRC to assume regulatory authority to license and regulate *radioactive* materials.
air quality	A measure of the concentrations of pollutants, measured individually, in the air.
alcove	A small excavation (room) off the main tunnel of a *repository* used for scientific study or for the installation of equipment.
aleatory	An inherent variation associated with the physical system or *environment*. Also referred to as variability, irreducible uncertainty, and stochastic uncertainty, random uncertainty.
alien species	With respect to a particular *ecosystem*, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.
alkalinity	Acid-neutralizing capacity of a substance. High alkalinity conditions can promote metal *corrosion*.
alignment	As used in the transportation analysis in this *Repository* SEIS, an engineered refinement of a rail corridor in which DOE would identify the location of a rail line.
Alloy-22	A *corrosion*-resistant, high-nickel alloy DOE would use for the outer shell of the *waste package*, for rails that support the drip shields, and for the parts of the emplacement pallet that would contact the waste package.
alluvial fan	A low, outspread, relatively flat-to-gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream where it issues from a narrow mountain valley on a plain or broad valley.
alluvium	A general term for the sedimentary material deposited by flowing water.
alpha particle	A positively charged particle ejected spontaneously from the nuclei of some *radioactive* elements. It is identical to a helium *nucleus* and has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). See *ionizing radiation.*

alternative	One of two or more actions, processes, or propositions from which a *decisionmaker* will determine the course to be followed. The *National Environmental Policy Act*, as amended, states that in the preparation of an *environmental impact statement*, an agency "shall ... study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" [42 U.S.C. 4321, Title I, Section 102 (E)]. The regulations of the Council on Environmental Quality that implement the *National Environmental Policy Act* indicate that the alternatives section is "the heart of the environmental impact statement" (40 CFR 1502.14), and include rules for presentation of the alternatives, including no action, and their estimated *impacts*. This *Repository* SEIS has two alternatives: the *Proposed Action*, under which DOE would construct, operate and monitor, and eventually close a *geologic repository* for the *disposal* of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain, and the *No-Action Alternative* under which DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate significant adverse environmental impacts and commercial utilities and DOE would continue to store and manage *spent nuclear fuel* and *high-level radioactive waste* at 76 sites in the United States in a manner that protected public health and safety and the *environment*. The *Nuclear Waste Policy Act* states that this Repository SEIS does not have to discuss alternatives to *geologic* disposal or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the Proposed Action.
alternative segments	Within an *alignment*, alternative segments are multiple routes DOE has selected for consideration. DOE would select one of them for the final *rail line*.
Amargosa Desert	The basin area south of Beatty, Nevada, and extending southeast about 80 kilometers (50 miles) to the area of Alkali Flat in California. The unincorporated town of Amargosa Valley, Nevada, is in the central portion of the *Amargosa Desert*. Amargosa Desert is also the name of *hydrographic area* number 230, which is part of the Death Valley Groundwater Region; both are designations used by the State of Nevada in its water planning and appropriations efforts. The boundaries of the Amargosa Desert *hydrographic area* closely resemble those of the geographic area.
Amargosa River	The main drainage system of the *Amargosa Desert*. The Amargosa River drainage basin originates in the Pahute Mesa-Timber Mountain area north of Yucca Mountain and includes the main tributary systems of *Beatty Wash* and *Fortymile Wash*. The river, which is frequently dry along much of its length, flows southeast through the Amargosa Desert and ends in the internal drainage system of Death Valley.

ambient
- Undisturbed natural conditions such as ambient temperature caused by climate or natural *subsurface* thermal gradients.
- Surrounding conditions.

ambient air
The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in the immediate proximity to emission sources.

ambient air quality standards
Standards established on a federal or state level that define the limits for airborne concentrations of designated *criteria pollutants* [*nitrogen dioxide*, *sulfur dioxide*, *carbon monoxide*, *particulate matter* with aerodynamic diameters less than 10 microns (PM_{10}), particulate matter with aerodynamic diameters less than 2.5 microns ($PM_{2.5}$), *ozone*, and lead] to protect public health with an adequate margin of safety (primary standards) and to protect public welfare, including plant and animal life, visibility, and materials (secondary standards). See *criteria pollutants*.

analytical periods
See *Repository SEIS analytical periods.*

analyzed land withdrawal area
Because the land has not yet been withdrawn, in this Repository SEIS it is referred to as the analyzed land withdrawal area. DOE uses the same analyzed land withdrawal area for the analyses in this Repository SEIS it used in the Yucca Mountain FEIS, an area of approximately 600 square kilometers (230 square miles or 150,000 acres).

aquifer
A *subsurface* saturated rock unit (formation, group of formations, or part of a formation) of sufficient *permeability* to transmit *groundwater* and yield usable quantities of water to wells and springs.

arid
- Area where mean annual evaporation exceeds mean annual precipitation.
- Area with insufficient rainfall to support agriculture.
- The hyper-arid zone (arid index 0.03) consists of dry land areas without vegetation with the exception of a few scattered shrubs. Annual rainfall is low, rarely exceeding 100 millimeters (4 inches). In the arid zone (arid index 0.03 to 0.20), the native vegetation is sparse, consisting of annual and perennial grasses and other herbaceous vegetation, and shrubs and small trees. There is high rainfall variability, with annual amounts that range from 100 to 300 millimeters (4 to 12 inches).

atomic mass
The mass of a neutral atom, based on a relative scale, usually expressed in atomic mass units. See *atomic weight.*

atomic number
The number of *protons* in an atom's *nucleus*.

atomic weight
The relative mass of an atom based on a scale in which a specific carbon atom (carbon-12) has a mass value of 12. Also known as relative *atomic mass*.

A-weighted decibel	See *decibel, A-weighted.*
backfill	The general fill that is placed in the excavated areas of an *underground facility*. Backfill for the proposed *repository* could be *tuff* or other material.
background radiation	*Radiation* from cosmic sources, naturally occurring *radioactive* materials such as granite, and global fallout from nuclear testing.
barrier	Any material, structure, or condition (as a thermal *barrier*) that prevents or substantially delays the movement of water or *radionuclides*. See *natural barrier*.
Beatty Wash	A tributary drainage to the *Amargosa River*; drains the west and north sides of the Yucca Mountain area.
best management practices	The processes, techniques, procedures, or considerations that DOE would employ to avoid or reduce the potential environmental *impacts* of its *Proposed Action* in a cost-effective manner while it met the *Yucca Mountain Repository* project objectives.
beta particle	A negatively charged *electron* or positively charged positron emitted from a *nucleus* during *decay*. Beta decay usually refers to a *radioactive* transformation of a *nuclide* by electron emission in which the *atomic number* increases by 1 and the mass number remains unchanged. In positron emission, the atomic number decreases by 1 and the mass number remains unchanged. See *ionizing radiation.*
biosphere	The ecosystem of the Earth and the living *organisms* that inhabit it.
boiling-water reactor	*A nuclear reactor* that uses boiling water to produce steam to drive a turbine.
borehole	For this *Repository* SEIS, a hole drilled to collect *site characterization* data or to supply water.
borosilicate glass	*High-level radioactive waste* matrix material in which boron takes the place of the lime used in ordinary glass mixtures. See *vitrification*.
buffer area	Area where railcars or trucks with *transportation casks* would wait until DOE moved them to a waste handling facility or shipped them off the site, and where the Department would store empty *waste packages* on site rail transfer carts until needed.
buffer car	A railcar that DOE would place at the front of a *cask* train between the locomotive and the first cask car and at the back of the train between the last cask car and the *escort car*. Federal regulations require the separation of a railcar that carries *spent nuclear fuel* and *high-level radioactive waste* from a locomotive, occupied caboose, carload of undeveloped film, or a railcar that carries another class of hazardous material by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

cancer	A malignant tumor of potentially unlimited growth, capable of invading surrounding tissue or spreading to other parts of the body.
candidate species	Species for which the U.S. Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.
canister	An unshielded metal container used as: • A pour mold in which molten vitrified *high-level radioactive waste* could solidify and cool. • A container in which DOE and electric utilities would place intact *spent nuclear fuel*, loose rods, or nonfuel components for shipping or storage. • In general, a container that provides *radionuclide confinement*. Canisters are used in combination with specialized overpacks that provide structural support, *shielding*, or confinement for storage, transportation, and *emplacement*. Overpacks used for transportation are usually referred to as *transportation casks*; those used for emplacement in a *repository* are referred to as *waste packages*.
Canister Receipt and Closure Facility	Facility that would receive DOE *disposable canisters* and TAD canisters, load canisters into *waste packages*, and close the waste packages.
carbon monoxide	A colorless, odorless, poisonous gas produced by incomplete fossil-fuel combustion; one of the six criteria pollutants for which there is a national *ambient air quality standard*.
carcinogen	An agent capable of producing or inducing *cancer*.
cask	• A heavily *shielded* container that meets applicable regulatory requirements used to ship *spent nuclear fuel* or *high-level radioactive waste*; • A heavily shielded container used by DOE and utilities for the *dry storage* of spent nuclear fuel; usable only for storage, not for transportation to or *emplacement* in a *repository*; or • A heavily shielded container that would be used by DOE to transfer *canisters* between waste handling facilities at the repository.
Cask Receipt Security Station	Facility that would perform initial waste receipt and inspection.
central operations area	The central operations area is an area in which DOE would develop approximately 0.8 kilometer (0.5 mile) southwest of the geologic repository operations area for all operations, which would include support and replacement of subsurface infrastructure in the Exploratory Studies Facility.

chain reaction	A process in which some *neutrons* released in one *fission* event cause other fission events that in turn release neutrons.
cladding	The metallic outer sheath of a fuel element generally made of stainless steel or a *zirconium alloy*. Its purpose is to isolate the fuel element from the external *environment.*
clastic	Describing a rock or sediment that consists mainly of broken fragments of preexisting minerals or rocks that have been transported from their places of origin.
closure	See *closure analytical period*.
closure analytical period	10 years – Overlaps the last 10 years of the monitoring period and includes activities that would begin upon receipt of a license amendment to close. Activities would include decommissioning and demolishing surface facilities, emplacing drip shields, backfilling, sealing subsurface-to-surface openings, restoring the surface to its approximate condition before repository construction, and constructing monuments to mark the site. See *Repository SEIS analytical periods*.
cloudshine	*Irradiation* of the human body by *neutrons* and *gamma rays* emitted by the passing plume of *radioactive* material.
commercial spent nuclear fuel	Commercial nuclear fuel rods that have been removed from *reactor* use at commercial nuclear power plants. See *spent nuclear fuel* and *DOE spent nuclear fuel.*
common segment	Portions of the rail alignment for which DOE has selected a single route for the rail line.
composite employment	Sum of direct and indirect employment.
construction	See *construction analytical period.*
construction analytical period	5 years – Begins upon receipt of the construction authorization from the Nuclear Regulatory Commission and ends prior to receipt of a license to receive and possess radiological materials. Activities would include site preparation, surface construction, and subsurface development. See *Repository SEIS analytical period.*
construction right-of-way	Nominally 150 meters (500 feet) on either side of the centerline of the *rail alignment*, with some variability. The right-of-way is generally linear but includes areas for support facilities such as quarries, water wells, and access roads.
contaminant	A substance that contaminates (pollutes) air, soil, or water. Also a hazardous substance that does not occur naturally or that occurs at levels greater than those that occur naturally in the surrounding *environment*.

contamination	The intrusion of undesirable elements (unwanted physical, chemical, biological, or radiological substances, or matter that has an adverse effect) to air, water, or land.
controlled area	The area restricted for the long term for the proposed *repository*, as identified by passive institutional controls DOE would install at closure. The controlled area would be 300 square kilometers (about 120 square miles) maximum surface and *subsurface* area that extended in the predominant direction of *groundwater* flow no farther south than 36 degrees, 40 minutes, 13.6661 seconds north latitude (the present southwest corner of the Nevada Test Site), and no more than 5 kilometers (3 miles) from the repository footprint in any other direction (see 40 CFR 197.12).
corridor	As used in the transportation analysis in this *Repository* SEIS, a strip of land, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a *rail line* to transport *spent nuclear fuel*, *high-level radioactive waste*, and other materials to and from the proposed *Yucca Mountain Repository*.
corrosion	The process of dissolving or wearing away gradually, especially by chemical action.
corrosion resistant material	Outer waste package material, such as Alloy-22, that corrodes slowly in a corrosive environment.
criteria pollutants	Six common pollutants (*ozone*, *carbon monoxide*, *particulate matter*, *sulfur dioxide*, lead, *and nitrogen dioxide*) known to be hazardous to human health and the environment and for which the U.S. Environmental Protection Agency sets National *Ambient Air Quality Standards* under the *Clean Air Act*. See *toxic air pollutants*.
cumulative impact	An *impact* on the *environment* that results from the incremental impact(s) of an action added to impacts from other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions that take place over a period.
curie	A unit of *radioactivity* equal to 37 billion disintegrations per second; also a quantity of any *nuclide* or mixture of nuclides having 1 curie of radioactivity.
day-night average sound level	The energy average of the *A-weighted decibel* sound levels over a 24-hour period. It includes an adjustment factor for noise between 10 p.m. and 7 a.m. to account for the greater sensitivity of most people to noise during the night.
decay (radioactive)	The process in which one *radionuclide* spontaneously transforms into one or more different radionuclides called decay products.

decibel (dB)	A standard unit for measuring sound pressure levels based on a reference sound pressure of 0.0002 dyne per square centimeter. This is the smallest sound a human can hear.
decibel, A-weighted (dBA)	A measurement of sound that approximates the sensitivity of the human ear, which is used to characterize the intensity or loudness of sound.
decisionmaker	The group or individual who would be responsible for making a decision on the construction and operation of a *geologic repository* for the disposal of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain.
decommissioning	The process of removal from service of a facility in which the handling of nuclear materials occurs. If nuclear materials have been handled at the facility, decommissioning includes decontamination of the facility so it can be dismantled or dedicated to other purposes.
dedicated train	A train that handles only one commodity. For the proposed railroad, this separate train with its own crew would limit switching between trains of the railcars carrying *spent nuclear fuel* and *high-level radioactive waste*.
detention pond	A low-lying area that is designed to temporarily hold a set amount of water while slowly draining to another location. They exist for flood control when large amounts of rain could cause flash flooding if not dealt with properly. The pond acts to reduce the peak runoff downstream by spreading the discharge out over a longer period.
direct employment	Jobs that are expressly associated with project activity.
direct impact	An effect that would result solely from the Proposed Action without intermediate steps or processes. Examples include habitat destruction, soil disturbance, air emissions, and water use.
disintegration	Any transformation of a *nucleus*, whether spontaneous or induced by *irradiation*, in which the nucleus emits one or more particles or *photons*.
disposable canister	A metal vessel for *DOE spent nuclear fuel* assemblies (including *naval spent nuclear fuel*) or solidified *high-level radioactive waste* suitable for storage, shipping, and *disposal*. At the *repository*, DOE would remove the *disposable canister* from the *transportation cask* and place it directly in a *waste package*. There are a number of types of disposable canisters, including standard canisters, multicanister overpacks, and TAD canisters.
disposal	For this *Repository* SEIS, the *emplacement* in a *repository* of *high-level radioactive waste*, *spent nuclear fuel*, or other highly *radioactive* material with no foreseeable intent of recovery, whether or not such emplacement would permit the recovery of such waste, and the *isolation* of such waste from the *accessible environment*.

distribution	As used in analyses of long-term performance, a range of values and probabilities associated with each value (or subrange of values) within the range. This can be in the form of a mathematical function or a table of values. See *normal distribution.*
DOE spent nuclear fuel	Nuclear fuel that has been withdrawn from a nuclear reactor, provided the constituent elements of the fuel have not been separated by reprocessing that DOE manages from its defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as from university and other research reactors, commercial reactor fuel acquired by DOE for research and development, and from foreign research reactors.
dose (radioactive)	The amount of *radioactive* energy taken into (absorbed by) living tissues.
dose equivalent	The product of absorbed dose in tissue multiplied by a quality factor and then sometimes multiplied by other necessary modifying factors at the location of interest. It is expressed numerically in rem. The dose equivalent quantity is used to compare the biological effectiveness of different kinds of radiation (based on the quality of radiation and its spatial distribution in the body) on a common scale.
drift	From mining terminology, a horizontal underground passage. In relation to the proposed *repository*, this includes excavations for *emplacement* (emplacement *drifts*), ventilation exhaust mains, access (access mains), and performance confirmation (observation *drift*).
drip shield	A corrosion-resistant *engineered barrier* that DOE would place above a *waste package* to prevent seepage water from direct contact with the waste package for thousands of years. The drip shield would also protect the waste package from rock fall.
dry storage	Storage of *spent nuclear fuel* without *immersion* of the fuel in water for cooling or *shielding*; it involves the encapsulation of spent fuel in a steel cylinder that might be in a concrete or massive steel *cask* or structure.
dual-purpose canister	A metal vessel suitable for storing (in a storage facility) and shipping (in a *transportation cask*) *commercial spent nuclear fuel* assemblies. At the *repository*, DOE would remove dual-purpose canisters from the transportation cask and open them. DOE would remove the spent nuclear *fuel assemblies* from the dual-purpose canister and place them in a TAD canister before placement in a *waste package*. The opened canister would be recycled or disposed of off the site as *low-level radioactive waste.*
duripan	A subsurface layer held together (cemented) by silica, usually containing other accessory cements.
earthquake	A series of elastic waves in the crust of the Earth caused by abrupt movement that eases strains built up along *geologic faults* or by volcanic action and that results in movement of the Earth's surface.

ecoregion	A relatively discrete set of ecosystems characterized by certain plant communities or assemblages.
ecosystem	A community of organisms and their physical environment interacting as an ecological unit.
electron	A stable elementary particle that is the negatively charged constituent of ordinary matter.
emplacement	The placement and positioning of *waste packages* in the proposed *repository*.
emplacement panels	Isolated areas in the proposed *repository* that DOE would set aside for waste *disposal*.
endangered species	An animal or plant species that is in danger of extinction throughout all or a significant part of its range.

Energy Policy Act of 1992 (Public Law 102-486, 106 Stat. 2776)

Legislation that amends the *Nuclear Waste Policy Act* by directing:

- The Environmental Protection Agency to set site-specific public health and safety *radiation* protection standards from Yucca Mountain, and
- The Nuclear Regulatory Commission to modify its technical requirements and licensing criteria to be consistent with the Environmental Protection Agency site-specific standards.

engineered barrier

The designed, or engineered, components of the proposed *underground facility* at Yucca Mountain, which would include the *waste packages* and other *barriers*.

environmental impact statement (EIS)

A detailed written statement that describes:

> ...the environmental impact of the proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; alternatives to the proposed action (although the *Nuclear Waste Policy Act*, as amended, precludes consideration of certain alternatives); the relationship between local short-term uses of man's *environment* and the *maintenance* and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Preparation of an environmental impact statement requires a public process that includes public meetings, reviews, and comments, as well as agency responses to the public comments.

environmental justice	The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental impacts that result from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies. Executive Order 12898, *Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations*, directs federal agencies to make the achievement of environmental justice part of their missions by identifying and addressing disproportionately high and adverse effects of agency programs, policies, and activities on minority populations and low-income populations.
epistemic	Lack of knowledge of quantities or processes of the system or the environment. Also referred to as subjective uncertainty, reducible uncertainty, and model form uncertainty.
erionite	A natural fibrous zeolite that is listed as a known human *carcinogen* by recognized international agencies such as the International Agency for Research on Cancer; it is present in the rocks in and around Yucca Mountain.
escort car	Railcar in which escort personnel would travel on a train that carried *spent nuclear fuel* or *high-level radioactive waste*.
evaporation pond	A containment pond with impermeable bottom and sides designed to hold liquid wastes and to concentrate the waste through evaporation.
evapotranspiration	The combined processes of evaporation and plant *transpiration* that remove water from the soil and return it to the air.
event	Any thing that happens discretely at a particular time; for example, an *earthquake* is an event.
Exploratory Studies Facility	An underground laboratory at Yucca Mountain that includes an 8-kilometer (5-mile) main loop (tunnel), a 3-kilometer (2-mile) *cross drift*, and a research *alcove* system for the performance of underground studies. The proposed repository could incorporate some or all of the Exploratory Studies Facility.
exposure (to radiation)	The incidence of *radiation* on living or inanimate material by *accident* or intent. Background exposure is the exposure to natural *ionizing radiation*. Occupational exposure is the exposure to ionizing radiation that occurs during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.
exposure pathway	The course a chemical or physical agent takes from the source to the exposed *organism*; it describes a unique mechanism by which an individual or population can become exposed to chemical or physical agents at or originating from a release site. Each exposure pathway includes a source or a release from a source, an exposure point, and an exposure route.

fault	A *fracture* or a fracture zone in crustal rocks along which there has been movement of the fracture's two sides in relation to one another, so what were once parts of one continuous rock *stratum* or vein are now separated.
fault-gouge material	Crushed and ground-up rock produced by friction between two sides of a *fault* when there is movement along the fault.
fission	The splitting of a *nucleus* into at least two other nuclei, which results in the release of two or three *neutrons* and a relatively large amount of energy.
floodplain	The lowlands adjoining inland and coastal waters, and relatively flat areas and flood-prone areas of offshore islands. Executive Order 11988 requires federal facilities to assess, at a minimum, actions in areas inundated by a 1-percent or greater chance flood in any given year. By DOE regulation (40 CFR Part 1022), the base floodplain is defined as the 100-year (1.0-percent) floodplain and the critical action floodplain is defined as the 500-year (0.2-percent) floodplain (see *100-year flood*).
Fortymile Wash	A major tributary to the *Amargosa River*; drains the east side of Yucca Mountain, *Jackass Flats* to the east of Yucca Mountain, and the Fortymile Canyon area to the north; usually dry along most of its length.
fracture	A general term for any break in a rock, whether or not it causes displacement, caused by mechanical failure from stress. *Fractures* include cracks, joints, and *faults*. Fractures can act as *pathways* for rapid *groundwater* movement.
fuel assembly	A number of fuel elements held together by structural materials for use in a *nuclear reactor*. Sometimes called a fuel bundle.
fugitive dust	*Particulate matter* composed of soil; can include emissions from haul roads, wind erosion of exposed soil surfaces, and other activities in which soil is removed or redistributed.
full time equivalent worker years	The number of employees who would be involved in an activity calculated from work hours. Each full-time equivalent worker year consists of 2,000 work hours (the number of hours DOE assumed for one worker in a normal work year).
gamma ray	High-energy, short wavelength, electromagnetic radiation emitted from the nucleus. Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium.
geologic	Of or related to a natural process that acts as a dynamic physical force on the Earth (faulting, erosion, mountain building resulting in rock formations, for instance).
geologic repository	A system for disposing of *radioactive* waste in excavated *geologic* media, which includes surface and *subsurface areas* of operation and the adjacent part of the geologic setting that provides *isolation* of radioactive waste in a *controlled area*.

geologic repository operations area	As defined at 10 CFR 63.2, the geologic repository operations area is "a *high-level radioactive waste* facility that is part of a *geologic repository*, including both surface and *subsurface* areas, where waste handling activities are conducted."
Great Basin	A subprovince of the Basin and Range province, generally characterized by north-trending mountain ranges and intervening basins, that stretches north to south from eastern Oregon to southern California, includes most of Nevada, and extends into western Utah.
Greater-Than-Class-C waste	*Low-level radioactive waste* generated by the commercial sector that exceeds U.S. Nuclear Regulatory Commission concentration limits for Class-C low-level waste, as specified in 10 CFR Part 61. DOE is responsible for disposing of this type of waste pursuant to the *Low-Level Radioactive Waste Policy Amendments Act of 1985*.
gross regional product	The value of all final goods and services produced in the *region of influence.*
groundshine	The *radiation dose* received from an area on the ground where a *radioactive* plume or cloud has deposited *radioactivity*.
groundwater	Water in pores or fractures in either the *unsaturated zone* or *saturated zone* below ground level.
habitat	Area in which a plant or animal lives and reproduces.
hazardous pollutant	Hazardous chemical that can cause serious health and environmental hazards, and that is listed on the federal list of hazardous air pollutants (42 U.S.C. Part 7412). See *toxic air pollutants.*
hazardous waste	Waste is designated as hazardous if it appears on the list of hazardous materials prepared by the EPA or a state or local regulatory agency, or if it has characteristics defined as hazardous by such agency. If the EPA does not list a material as hazardous, it still may be considered a hazardous waste if it exhibits one of the four characteristics defined in 40 CFR 261 Subpart C: Ignitability, corrosivity, reactivity, or toxicity.
heavy-haul truck	An overweight, overdimension vehicle that must have permits from state highway authorities to use public highways; a vehicle DOE would use on public highways to move *spent nuclear fuel* or *high-level radioactive waste shipping casks* designed for a railcar.
heavy metal	In the context of this *Repository* SEIS, all uranium, plutonium, and thorium used or generated in a manmade *nuclear reactor*.

high-level radioactive waste

1. The highly *radioactive* material that resulted from the reprocessing of *spent nuclear fuel*, which includes liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains *fission* products in sufficient concentrations. (NOTE: DOE would vitrify liquid high-level radioactive waste before shipping it to the proposed *repository*.)

2. Other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent *isolation*.

human intrusion

The inadvertent penetration into the *repository* by people.

hydric

Describes soils that are characterized by the presence of considerable moisture.

hydrographic area

In reference to Nevada *groundwater*, divisions of the state into groundwater basins and subbasins based primarily on topographic features such as mountains and valleys. The state uses the map of hydrographic areas as the basis for water planning, management, and administration. (Because they are based heavily on topographic features, hydrographic area boundaries sometimes differ from groundwater basin designations developed from studies of inferred or measured groundwater flow patterns.)

hydrology

1. The study of water characteristics, especially the movement of water, or

2. The study of water, involving aspects of *geology*, oceanography, and meteorology.

immersion

See *cloudshine*.

impact

The positive or negative effect of an action (past, present, or future) on the natural *environment* (land use, air quality, water resources, geological resources, ecological resources, aesthetic and scenic resources) and the human environment (infrastructure, economics, social, and cultural).

in situ

In its natural position or place. The phrase distinguishes in-place experiments, conducted in the field or *underground facility*, from those conducted in the laboratory.

incident-free

Routine transportation in which cargo travels from origin to destination without being involved in an *accident*.

indirect employment

Jobs that are created as a result of expenditures by directly employed project workers (for example, restaurant workers or childcare providers) or jobs that are created by project-related purchases of goods and services (for example, sales manager of a concrete supply store).

indirect impact

An effect that is related to but removed from a proposed action by an intermediate step or process. Examples include surface-water quality changes resulting from soil erosion at construction sites, and reductions in productivity resulting from changes in soil temperature.

indurated	Hardened, as in a subsurface layer that has become hardened.
industrial waste	*Solid waste* that is neither hazardous nor radioactive such as construction and demolition debris, rubber, and miscellaneous plastic products. Examples of construction and demolition debris include soil, rock, masonry materials, and lumber.
industrial wastewater	Liquid wastes from industrial processes that do not include sanitary sewage. *Repository* industrial wastewater would include water for dust suppression, rinse water from concrete production and transport, and process water from building heating, ventilation, and air conditioning systems.
infrastructure	Basic facilities, services, and installations for the functioning of a community or society, such as transportation and communication systems. For the proposed *repository*, these would include surface and *subsurface* facilities (for example, service *drifts*, transporters, electric power supplies, waste handling buildings, and administrative facilities).
Initial Handling Facility	A facility that would receive *high-level radioactive waste* and *naval spent nuclear fuel* canisters, load canisters into waste packages, and close the waste packages.
institutional control	Monitoring and *maintenance* of storage facilities to ensure that radiological releases to the *environment* and *radiation doses* to workers and the public remain within federal limits and DOE Order requirements, as applicable. For the proposed *repository*, active institutional control would require the presence of humans to safeguard and maintain the site; passive institutional control would include such devices as permanent markers and land records to warn future generations of dangers.
invasive species	An *alien species* whose introduction does or is likely to cause economic or environmental harm or harm to human health.
invert	The structure constructed in a *drift* to provide the floor of that drift. Drifts are made by boring machines and have a round bottom. The invert makes the bottom of the drift flat.
involved worker	Nonradiological impacts: A worker who would be doing the physical work of constructing, operating, monitoring, and closing the repository. Radiological impacts: A worker who would be directly engaged in the activities related to subsurface construction and operations at the proposed repository, which would include subsurface excavation activities; receipt, handling, packaging, and emplacement of waste materials; and monitoring of the condition and performance of the waste packages. See *noninvolved worker*.
ion	1. An atom that contains excess *electrons* or is deficient in electrons, which causes it to be chemically active, or 2. An electron not associated with a *nucleus*.

ionizing radiation	1. *Alpha particles*, *beta particles*, *gamma rays*, *X-rays*, *neutrons*, high-speed *electrons*, high-speed *protons*, and other particles capable of producing *ions*. 2. Any *radiation* capable of the displacement of electrons from an atom or molecule, thereby producing ions.
irradiation	*Exposure* to *radiation.*
isolation	Inhibition of the transport of *radioactive* material so the amounts and concentrations of the material that enters the accessible *environment* stay within prescribed limits.
Jackass Flats	A broad asymmetric basin 8 to 10 kilometers (5 to 6 miles) wide and 20 kilometers (12 miles) long that is east of Yucca Mountain and is drained by *Fortymile Wash*. Also the name of the hydrographic area (Area 227A) overlapping the same general land area and from which DOE would withdraw groundwater to support the Proposed Action.
land withdrawal area	The area of federal property that DOE owns, leases, or otherwise controls for the *Yucca Mountain site*.
latent cancer fatality	A death that results from *cancer* that *exposure* to *ionizing radiation* caused. There typically is a latent period between the time of the *radiation* exposure and the time the cancer cells become active.
legal weight truck	A truck with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be within Federal and state regulations.
lost workday case	A case that involves days away from work or days of restricted work activity, or both. Equivalent to Days Away, Restricted, or On Job Transfer case in the CAIRS database.
low-income	Below the poverty level as defined by the Bureau of the Census.
low-income population	A population in which 20 percent or more of the persons live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements.
low-level radioactive waste	Radioactive waste that is not classified as *high-level radioactive waste*, *transuranic waste*, byproduct material containing uranium or thorium from processed ore, or naturally occurring *radioactive* material. The *repository* low-level radioactive waste would include personal protective clothing, air filters, solids from the liquid low-level waste treatment process, radiological control and survey waste, and used canisters (dual-purpose).

mapping zone	Biogeographically unique areas the *Southwest Regional Gap Analysis Project* derived from existing ecoregion maps using a combination of topographic and soil information, which it then truncated at state boundaries. Mapping zones are subunits of *ecoregions*.
matrix	The solid, but porous, portion of the rock.
maximally exposed individual	A hypothetical individual whose location and habits result in the highest total radiological or chemical *exposure* (and thus *dose*) from a particular source for all exposure routes *pathways* (for example, inhalation, ingestion, direct exposure).
maximum contaminant level	Under the Safe Drinking Water Act, the maximum permissible concentrations of specific constituents in drinking water that is delivered to any user of a public water system that serves 15 or more connections and 25 or more people; the standards established as maximum contaminant levels consider the feasibility and cost of attaining the standard.
mesosphere	Belt of atmosphere, just above the stratosphere, from 50 to 80 kilometers (30 to 50 miles) above the Earth's surface.
metric tons of heavy metal (MTHM)	Quantities of *spent nuclear fuel* are traditionally expressed in terms of MTHM (typically uranium, but including plutonium and thorium), without the inclusion of other materials such as *cladding* (the tubes that contain the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 short tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One MTHM disposed of as spent nuclear fuel would fill a space approximately the size of the refrigerated storage area in a typical household refrigerator.
midpillar	The rock section between adjacent *emplacement drifts*.
millirem	One one-thousandth (0.001) of a *rem*.
minority	Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other nonwhite person.
minority population	A community in which the percent of the population of a racial or ethnic minority is 10 points higher than the percent found in the population as a whole.
mitigation	Actions and decisions that: • Avoid *impacts* altogether by not taking a certain action or parts of an action; • Minimize impacts by limiting the degree or magnitude of an action;

mitigation (continued)	• Rectify the impact by repairing, rehabilitating, or restoring the *affected environment*; • Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action; or • Compensate for an impact by replacing or providing substitute resources or environments.
mixed-oxide fuel	A mixture of uranium oxide and plutonium oxide that could be used to power commercial *nuclear reactors*.
mixed waste	Waste that exhibits the characteristics of both hazardous and *low-level radioactive wastes.*
monitoring	Activities during the *repository* operations and *monitoring analytical periods* that would include the surveillance and testing of *waste packages* and the repository for *performance confirmation*. See *monitoring analytical period.*
monitoring analytical period	50 years – Begins upon emplacement of the final waste package. Activities would include maintaining active ventilation of the repository for as long as 50 years, remotely inspecting waste packages, and continuing investigations in support of predictions related to postclosure performance. See *Repository SEIS analytical periods.*
Monte Carlo sampling technique	Technique for the random generation of inputs from probability distributions to simulate the process of sampling from the actual population.
National Environmental Policy Act, as amended (NEPA; 42 U.S.C. 4321 et seq.)	The Federal statute that is the national charter for protection of the *environment*. The Act is implemented by procedures issued by the Council on Environmental Quality and DOE.
native species	With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.
natural barrier	The physical components of the *geologic environment* that individually and collectively act to limit the movement of water or, in relation to this *Repository* SEIS, *radionuclides*. See *barrier*.
naval spent nuclear fuel	*Spent nuclear fuel* discharged from *reactors* in surface ships, submarines, and training reactors operated by the U.S. Navy.
neutron	An atomic particle with no charge and an *atomic mass* of 1; a component of all atoms except hydrogen; frequently released as *radiation*.

Nevada Administrative Code 503 and 527	The State of Nevada designates special status animal species as endangered, threatened, protected, and sensitive under Nevada Administrative Code 503. Fully protected plants that are declared to be critically endangered and threatened with extinction are protected under Nevada Administrative Code 527.
nitrogen dioxide	See *nitrogen oxides.*
nitrogen oxides	Gases formed in great part from atmospheric nitrogen and oxygen when combustion occurs under conditions of high temperature and high pressure; a major air pollutant. Two primary nitrogen oxides, nitric oxide (NO) and *nitrogen dioxide* (NO_2), are important airborne *contaminants*. Nitric oxide combines with atmospheric oxygen to produce nitrogen dioxide. Both nitric oxide and nitrogen dioxide can, in high concentration, cause lung cancer. Nitrogen dioxide is a *criteria pollutant*.
No-Action Alternative	The *Nuclear Waste Policy Act* states that this *Repository* SEIS does not have to discuss *alternatives* to *geologic disposal* or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the *Proposed Action*. For this SEIS, under the No-Action Alternative DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate significant adverse environmental impacts. Commercial utilities and DOE would continue to store and manage *spent nuclear fuel* and *high-level radioactive waste* at 76 sites in the United States in a manner that protected public health and safety and the *environment*. See *alternative*.
nonattainment area	An area that does not meet the *ambient air quality standard* for one or more *criteria pollutants*. Further designations (for example, serious, moderate) describe the magnitude of the nonattainment.
noninvolved worker	Nonradiological impacts: A worker who would perform managerial, technical, supervisory, or administrative activities but would not be directly involved in construction, excavation, or operations activities. Radiological impacts: Noninvolved workers would be managerial, technical, supervisory, and administrative personnel and workers engaged in surface construction during the construction period and the first several years of repository operations, when surface and subsurface construction and operations would proceed in parallel. Noninvolved workers include DOE Nevada Test Site workers. See *involved worker*.
nonnative species	A species found in an area where it has not historically been found.
normal distribution	As used in analyses of long-term performance, a special type of symmetrical distribution known in the science of statistics as the Gaussian Distribution and commonly known as the "bell-shaped curve." See *distribution.*
North Construction Portal	*Portal* that would be used for construction of the *subsurface* facility.

North Portal	An existing *portal (*current access to the *Exploratory Studies Facility*) that DOE would use initially for subsurface construction and to emplace *waste packages* in the subsurface facility.
North Ramp	An existing, gently sloping incline that begins at the *North Portal* on the surface and extends through the *subsurface* to the edge of the *subsurface facility*. It would support *waste package emplacement* operations.
noxious weed	Any species of plant which is, or is likely to be, detrimental or destructive and difficult to control or eradicate.
nuclear reactor	A device in which a nuclear *fission chain reaction* can be initiated, sustained, and controlled to generate heat or to produce useful *radiation*.
Nuclear Waste Policy Act (NWPA; 42 U.S.C. 10101 et seq.)	The federal statute, originally enacted in 1982 (Public Law 97-425; 96 Stat. 2201), that established the Office of Civilian *Radioactive* Waste Management and defines its mission to develop a federal system for the management and *geologic disposal* of *commercial spent nuclear fuel* and other *high-level radioactive wastes*, as appropriate. The Act specifies other federal responsibilities for nuclear waste management, establishes the Nuclear Waste Fund to cover the cost of geologic disposal, authorizes interim storage under certain circumstances, and defines interactions between federal agencies and the states, local governments, and Native American tribes. Congress amended the Act substantially in 1987 (see *Nuclear Waste Policy Act Amendments of 1987*) and 1992 (see *Energy Policy Act of 1992*).
Nuclear Waste Policy Act Amendments of 1987 (Public Law 100-203; 101 Stat. 1330)	Legislation that amended the *Nuclear Waste Policy Act* to limit repository *site characterization* activities to Yucca Mountain, Nevada; establish the Office of Nuclear Waste Negotiator to seek a state or Native American tribe willing to host a *repository* or monitored retrievable storage facility; create the *Nuclear Waste Technical Review Board*; and increase state and local government participation in the waste management program.
Nuclear Waste Technical Review Board	An independent body in the executive branch, created by the *Nuclear Waste Policy Amendments Act of 1987* to provide independent scientific and technical oversight of DOE's program for managing and disposing of *high-level radioactive waste* and *spent nuclear fuel*. The President appoints Board members from a list prepared by the National Academy of Sciences.
nucleus	The central, positively charged, dense portion of an atom. Also known as atomic nucleus.
nuclide	An atomic *nucleus* specified by its *atomic weight*, *atomic number*, and energy state; a *radionuclide* is a *radioactive* nuclide.
operations	See *operations analytical period.*
operational phases	Four stages used in the license application to indicate when specific facilities are expected to be operational under the planned phased construction. Operational phases are Phase 1, Phase 2, Phase 3, and Phase 4.

operations analytical period	50 years – Begins upon receipt of a license to receive and possess radiological materials and ends upon emplacement of the final waste package. Activities would include receipt, handling, aging, emplacement, and monitoring of waste, as well as continued construction of surface and subsurface facilities. See *Repository SEIS analytical periods.*
organism	An individual constituted to carry on the activities of life by means of organs separate but mutually dependent; a living being.
overweight, overdimension truck	Semi- and tandem tractor-trailer trucks with gross weights over 80,000 pounds that must obtain permits from state highway authorities to use public highways.
ozone (O_3)	The triatomic form of oxygen; in the *stratosphere*, ozone protects the Earth from the Sun's *ultraviolet radiation*, but in lower levels of the atmosphere it is an air pollutant.
particulate matter	Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. See $PM_{2.5}$ and PM_{10}.
pathway	A potential route by which radionuclides might reach the *accessible environment* and pose a threat to humans.
perceived risk	How an individual perceives the amount of risk from a certain activity.
perched water	A *saturated zone* condition that is not continuous with the *water table* because an impervious or semipervious layer underlies the perched zone or a *fault* zone creates a *barrier* to water movement and perches water. See *permeable.*
performance confirmation	The program of tests, experiments, and analyses DOE conducted to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the *repository* would meet the performance objectives for the period after *permanent closure*.
permanent closure	Final sealing of *shafts* and *boreholes* of the *underground facility*, which would include the installation of permanent monuments to mark the location and boundaries of the *repository*.
permeability	In general terms, the capacity of such mediums as rock, sediment, and soil to transmit liquid or gas. Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they interconnect. "Hydraulic conductivity" is equivalent to "permeability" in technical discussions of *groundwater*.
permeable	Pervious; a permeable rock is a rock, either porous or cracked, that allows water to soak into and pass through it freely.

person-rem	A unit to measure the *radiation exposure* to an entire group and to compare the effects of different amounts of radiation on groups of people; it is the product of the average *dose equivalent* (in *rem*) to a given organ or tissue multiplied by the number of persons in the population of interest.
petrocalcic	A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or *indurated*.
photon	A massless particle, the quantum of an electromagnetic field, that carries energy, momentum, and angular momentum.
picocurie per liter (or gram)	A unit of concentration measure that describes the amount of *radioactivity* (in picocuries) in volume (or mass) of a given substance [typically, air or water (by volume) or soil (by mass)]. A picocurie is one-trillionth of a *curie*.
piedmont	Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.
$PM_{2.5}$	*Particulate matter* with an aerodynamic diameter of 2.5 micrometers or less (about 0.0001 inch). This fine particulate matter is able to penetrate to the deepest part of the lungs and poses a risk to human health.
PM_{10}	*Particulate matter* with an aerodynamic diameter less than or equal to a nominal 10 micrometers (about 0.0004 inch). Particles smaller than this diameter are small enough to be breathable and could be deposited in lungs.
population dose	A summation of the *radiation doses* received by individuals in an exposed population; equivalent to collective dose; expressed in *person-rem*.
portal	A portal is the opening to the *subsurface facility* that would provide access for construction, equipment, rock removal, and waste *emplacement.*
Postclosure	The timeframe after permanent closure of the repository through the 1 million years analyzed in this Repository SEIS.
preclosure	The timeframe from construction authorization to repository closure.
pressurized-water reactor	A nuclear power *reactor* that uses water under pressure as a coolant. The water boiled to generate steam is in a separate system.
primarily canistered fuel approach	The packaging of most (a goal of 90 percent) *commercial spent nuclear fuel* at the commercial sites in multipurpose transportation, aging, and disposal canisters. The remaining commercial spent nuclear fuel (about 10 percent) would arrive at the *repository* as *uncanistered spent nuclear fuel* or in *dual-purpose canisters*.

prime farmland

Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not eligible). It has the soil quality, growing season, and moisture supply necessary for the economic production of sustained high yields of crops when treated and managed (including water management) in accordance with acceptable farming methods.

probabilistic

(1) Based on or subject to *probability*. (2) Involving a variable factor, such as temperature or porosity. At each instance of time, the factor can take on any of the values of a specified set with a certain probability. Data from a probabilistic process is an ordered set of observations, each of which is one item in a probability *distribution*.

probability

The relative frequency at which an event can occur in a defined period. Statistical probability is about what happens in the real world and is verifiable by observation or sampling. Knowledge of the exact probability of an event is usually limited by the inability to know, or compile the complete set of, all possible outcomes over time or space. Probability is measured on a scale of 0 (event will *not* occur) to 1 (event *will* occur).

process

Any phenomenon that occurs over a relatively long period. An example of a process is general corrosion of metal. As opposed to an event which occurs relatively instantaneously.

proposed action

The activity proposed to accomplish a federal agency's purpose and need. An environmental impact statement analyzes the environmental *impacts* of the proposed action. A proposed action includes the project and its related support activities (preconstruction, construction, and operation, along with postoperational requirements). The Proposed Action in this Repository SEIS is the construction, operation and monitoring, and eventual closure of a *geologic repository* for *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain in Nevada.

proposed action inventory

Materials planned for *disposal* at the *Yucca Mountain repository*.

proton

An elementary particle that is the positively charged component of ordinary matter and, together with the *neutron*, is a building block of all atomic nuclei.

pyroclastic

Of or related to individual particles or fragments of *clastic* rock material of any size formed by volcanic explosion or ejected from a volcanic vent.

qualitative

In relation to a variable, a parameter, or data, an expression or description of an aspect in terms of nonnumeric qualities or attributes. See *quantitative*.

quantitative

A numeric expression of a variable. See *qualitative.*

rad

A unit of absorbed *radiation dose* in terms of energy. One rad equals 100 ergs of energy absorbed per gram of tissue. (The word derives from *radiation absorbed dose*.)

radiation	The emitted particles or *photons* from the nuclei of *radioactive* atoms. Some elements are naturally radioactive; others are induced to become radioactive by *irradiation* in a *reactor*. Naturally occurring radiation is indistinguishable from induced radiation.
radioactive	Emitting *radioactivity*.
radioactivity	The property possessed by some elements (for example, uranium) of spontaneously emitting *alpha*, *beta*, or *gamma rays* by the *disintegration* of atomic nuclei.
radionuclide	See *nuclide*.
rail alignment	A strip of land less than 400 meters (0.25 mile) wide within a corridor within which DOE would specify the location of a rail line.
rail corridor	A strip of land 400 meters (0.25 mile) wide through which DOE would identify an alignment for the construction of a rail line.
rail line	An engineered feature that consists of the track, ties, ballast, and subballast at a specific location.
railroad	A transportation system that incorporates the rail line, rail line operations support facilities, railcars, locomotives, and other related property and infrastructure.
reactor	See *nuclear reactor*.
real disposable income	The dollar income, including the value of transfer payments, available to individuals after taxes have been paid; also referred to as real disposable personal income.
reasonably maximally exposed individual	See *receptor*.
Receipt Facility	A facility for the transfer of TAD and *dual-purpose canisters*, as appropriate, to the *Wet Handling Facility*, a *Canister Receipt and Closure Facility*, and the *aging pads*.
receptor	A hypothetical person who is exposed to environmental *contaminants* (in this case *radionuclides*) in such a way—by a combination of factors that include location, lifestyle, dietary habits, etc.—that this individual is representative of the *exposure* of the general population. DOE used this hypothetical individual to evaluate long-term *repository* performance. The receptor represents the reasonably maximally exposed individual defined in 40 CFR Part 197. See *maximally exposed individual.*
Record of Decision	A document that provides a concise public record of a decision made by a government agency.

recordable cases	Occupational injuries or occupation-related illnesses that result in: 1. A fatality, regardless of the time between the injury or the onset of the illness and death, 2. *Lost workday cases* (nonfatal), or 3. The transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.
region of influence (the region)	A specialized term that indicates a specific area of study for each of the resource areas that this *Repository* SEIS analysis addresses.
release fraction	The fraction of each radionuclide in *spent nuclear fuel* or *high-level radioactive waste* that could be released from a containment in an *accident*.
rem	The unit of effective *dose equivalent* from ionizing radiation to the human body. It is an expression of the amount of radiation to which a person has been exposed. The effective dose equivalent in rem is equal to the absorbed dose in rad multiplied by quality and weighting factors that are necessary because biological effects can vary both by the type of radiation (even of the same deposited energy) and by the specific tissue exposed. (The word derives from *roentgen equivalent in man*).
repository	See *Yucca Mountain Repository.*
Repository SEIS analytical periods	Four timeframes DOE defined for use in this *Repository* SEIS to best evaluate potential preclosure environmental impacts: • *Construction analytical period*: 5 years – Begins upon receipt of the construction authorization from the Nuclear Regulatory Commission and ends prior to receipt of a license to receive and possess radiological materials. Activities would include site preparation, surface construction, and subsurface development. • *Operations analytical period*: 50 years - Begins upon receipt of a license to receive and possess radiological materials and ends upon emplacement of the final waste package. Activities would include receipt, handling, aging, emplacement, and monitoring of waste, as well as continued construction of surface and subsurface facilities. • *Monitoring analytical period*: 50 years – Begins upon emplacement of the final waste package. Activities would include maintaining active ventilation of the repository for as long as 50 years, remotely inspecting waste packages, and continuing investigations in support of predictions related to postclosure performance.

Repository SEIS analytical periods (continued)	• *Closure analytical period*: 10 years – Overlaps the last 10 years of the monitoring period and includes activities that would begin upon receipt of a license amendment to close. Activities would include decommissioning and demolishing surface facilities, emplacing drip shields, backfilling, sealing subsurface-to-surface openings, restoring the surface to its approximate condition before repository construction, and constructing monuments to mark the site.
restricted area	The restricted area, as defined at 10 CFR 20.1003 and 10 CFR 63.2, is an area in which DOE would separate waste handling operations from other activities in the *geologic repository operations area.* During phased *construction*, the restricted area would separate operational waste handling facilities from waste handling facilities under construction. DOE would monitor the restricted area to ensure adequate safeguards and security for *radioactive* materials.
resuspension	The renewed suspension into the atmosphere of material that had once settled to the ground.
retention pond	A pond designed to hold up to a specific amount of water indefinitely.
retrieval	The act of removing *radioactive* waste from the underground location at which the waste had been previously emplaced for disposal. Retrieval would be a contingency action, performed only if the waste needed to be retrieved in order to protect the public health and safety or the environment or to recover resources from *spent nuclear fuel*.
riprap	Broken stones or chunks of concrete used as foundation material or in embankments to control water flow or prevent erosion.
risk	The product of the *probability* that an undesirable *event* will occur multiplied by the consequences of the undesirable event.
sanitary sewage	Domestic wastewater from, sinks, showers, kitchens, floor drains, restrooms, change rooms, and food preparation and storage areas.
sanitary waste	*Solid waste* that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. (State of Nevada waste regulations define this waste stream as household waste.)
saturated zone	The region below the *water table* where water completely fills all spaces (*fractures* and rock pores).
sedimentary rock	Rock formed by the accumulation and consolidation of sediment in water or land, usually in layered deposits. Sandstone, limestone, dolomite, and shale are types of sedimentary rocks DOE has identified in this *Repository* SEIS. They are differentiated by chemistry, deposition, and texture.
seismic	Pertaining to, characteristic of, or produced by *earthquakes* or earth vibrations.

seismicity — A seismic event or activity such as an *earthquake* or earth tremor; *seismic* action. Often used in reference to the study of earthquakes over time and the probability of an earthquake occurring in a specific location.

sensitive species — As designated by the Bureau of Land Management, native species other than federally listed, proposed, or candidate species that the State Director deems to be in need of protection to ensure that actions authorized, funded, or carried out do not contribute to the need for the species to become listed under the Endangered Species Act. Bureau of Land Management Manual 6840.06 E provides the factors by which a native species may be listed as sensitive.

shaft — For the *Yucca Mountain Repository*, an excavation or vertical passage of limited area, in comparison to its depth, DOE would use to ventilate underground facilities.

shielding — Any material that provides *radiation* protection.

shielded transfer cask — A metal vessel used to transfer canisters between waste handling facilities.

shipment — The movement of a properly prepared (loaded, unloaded, or empty) *cask* from one site to another and associated activities to ensure compliance with applicable regulations.

shipping cask — A heavily shielded massive container that would meet regulatory requirements for the shipment of *spent nuclear fuel* or *high-level radioactive waste*. See *cask.*

site characterization — Activities associated with the determination of the suitability of the *Yucca Mountain site* as a *geologic repository*. DOE constructed the *Exploratory Studies Facility* to support the following activities related to the determination of site suitability, which would include surface facilities and *subsurface* ramps and *drifts*:

- Gather and evaluate surface and subsurface site data,
- Predict the performance of the *repository*,
- Prepare the repository design, and
- Assess the performance of the system against the required Code of Federal Regulations and program performance criteria.

soil map unit	A conceptual group of one or more map delineations identified by the same name in a soil survey that represent similar landscape areas that consist of either: 1. The same kind of component soils, with inclusions of minor or erratically dispersed soils; or 2. Two or more kinds of component soils that might or might not occur together in various delineations but that have similar special use and management properties.
soil order	The broadest category of soil classification, identified by the presence or absence of diagnostic layers, or horizons, which have specific physical, chemical, and biological properties.
soil series	The lowest category of soil taxonomy with the most restrictive classification of soil properties.
solid cancer	Solid cancers include all malignant neoplasms other than those of the lymphatic and hematopoietic tissue.
solid waste	For this *Repository* SEIS analysis, nonhazardous general household waste.
source term	Types and amounts of radionuclides that are the source of a potential release of *radioactivity*.
South Portal development area	An existing *portal* and ramp (current access to the *Exploratory Studies Facility*) that DOE would use for construction of the *subsurface facility*.
Southwest Regional Gap Analysis Project	2004 project was a multi-institutional effort to map and assess biodiversity for approximately 1.45 million square kilometers (560,000 square miles) in the southwestern United States. One task of this project was the development of a land cover map for the region.
Special-Performance-Assessment-Required wastes	Low-level radioactive wastes generated in DOE production reactors, research reactors, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.
spent nuclear fuel	1. *Nuclear reactor* fuel that has been used to the extent that it can no longer effectively sustain a *chain reaction*. 2. Fuel that has been withdrawn from a nuclear reactor after *irradiation*, the component elements of which have not been separated by reprocessing. For this project, this refers to: a. Intact, nondefective *fuel assemblies*, b. Failed fuel assemblies in canisters, c. Fuel assemblies in canisters,

spent nuclear fuel (continued)	d. Consolidated fuel rods in canisters, e. Nonfuel assembly hardware inserted in pressurized-water reactor fuel assemblies, f. Fuel channels attached to boiling-water reactor fuel assemblies, and g. Nonfuel assembly hardware and structural parts of assemblies resulting from consolidation in canisters.
stigma	An undesirable attribute that blemishes or taints an area or locale.
stratigraphic units	A layer or body of rock, distinct from that above or below, based on a specific property or characteristic of the rock. (A stratigraphic unit based on one rock property may not coincide with the unit designation based on another property.)
stratigraphy	The branch of geology that deals with the definition and interpretation of rock strata, the conditions of their formation, character, arrangement, sequence, age, distribution, and especially their correlation by the use of fossils and other means of identification. See *stratum*.
stratosphere	The atmospheric shell above the *troposphere* and below the *mesosphere*. It extends from 10 to 20 kilometers (6 to 12 miles) to about 53 kilometers (33 miles) above the surface.
stratum	A sheet-like mass of *sedimentary rock* or earth of one kind between beds of other kinds.
subsurface	A zone below the surface of the Earth, the *geologic* features of which are principally layers of rock that have been tilted or faulted and are interpreted on the basis of drill hole records and geophysical (seismic or rock vibration) evidence. In general, it is all rock and solid materials lying beneath the Earth's surface.
subsurface facility (subsurface geologic repository operations area)	The structure, equipment and systems (such as ventilation), *backfill* materials if any, and openings that penetrate underground (for example, ramps, *shafts*, and *boreholes*, including their seals).
sulfur dioxide (SO_2)	A pungent, colorless gas produced during the burning of sulfur-containing fossil fuels. It is the main pollutant involved in the formation of acid rain. Coal- and oil-burning electric utilities are the major source of sulfur dioxide in the United States. Inhaled sulfur dioxide can damage the human respiratory tract and can severely damage vegetation. See *criteria pollutants*, *ambient air quality standards*.
threatened species	A species that is likely to become endangered in the foreseeable future throughout all or a significant part of its range.

threshold limit values	The airborne concentration of a material to which nearly all persons can be exposed day after day, for a normal 8-hour workday or 40-hour workweek, without adverse effects; term used by the American Conference of Governmental Industrial Hygienists.
total employment	The sum of direct and indirect employment resulting from initiation of an activity. Direct employment consists of jobs performing the activity. Indirect employment consists of jobs in other activities supporting the direct employees. Also defined as composite employment.
total recordable cases	The total number of work-related deaths, illnesses, or injuries that resulted in the loss of consciousness, restriction of work or motion, transfer to another job, or required medical treatment beyond first aid.
total effective dose equivalent	An expression of the *radiation* dose received by an individual from external radiation and from *radionuclides* internally deposited in the body; often generically referred to as *dose*. All doses presented in this Repository SEIS are in terms of total effective dose.
Total System Performance Assessment	A *risk* assessment that quantitatively estimates how the proposed *Yucca Mountain Repository* system could perform under the influence of specific features, events, and processes, incorporating uncertainty in the models and data.
toxic air pollutant	*A hazardous pollutant* not listed as a *criteria pollutant* or a hazardous pollutant.
traditional cultural property	A property that is eligible for inclusion in the *National Register of Historic Places* because of its association with cultural practices or beliefs of a living community that are rooted in that community's history, and are important in the maintenance of the continuing cultural identity of the community. Culture includes the traditions, beliefs, practices, lifeways, arts, crafts, and social institutions of a community, whether an American Indian tribe, a local ethnic group, or the people of the Nation as a whole. Properties can include buildings, structures, and sites; groups of buildings, structures, or sites that form historic districts; and individual objects.
transpiration	The process by which water enters a plant through its root system, passes through its vascular system, and is released into the atmosphere through openings in its outer covering. It is an important process for removal of water that has infiltrated below the zone where it could be removed by evaporation.
transportation, aging, and disposal (TAD) canister	A canister suitable for storage, shipping, and *disposal* of *commercial spent nuclear fuel*. Commercial spent nuclear fuel would be placed directly into a TAD canister at the commercial *reactor*. At the *repository*, DOE would remove the TAD canister from the *transportation cask* and place it directly into a *waste package* or an *aging overpack*. The TAD canister is one of a number of types of *disposable canisters*.
transportation cask	A vessel that meets applicable regulatory requirements for transport of *spent nuclear fuel* or *high-level radioactive waste* via public transportation routes.

transuranic waste	Waste materials (excluding high-level radioactive waste and certain other waste types) contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and that occur in concentrations greater than 100 nanocuries per gram. Transuranic waste results primarily from treatment and fabrication of plutonium and from research activities at DOE defense installations.
troposphere	The lowest layer of the atmosphere; it contains about 95 percent of the mass of air in the Earth's atmosphere. The troposphere extends from the Earth's surface up to about 10 to 15 kilometers (6 to 9 miles).
tuff	Igneous rock formed from compacted volcanic fragments from *pyroclastic* (explosively ejected) flows with particles generally smaller than 4 millimeters (about 0.16 inch) in diameter—the most abundant type of rock at the *Yucca Mountain site*. Nonwelded tuff results when volcanic ash cools in the air sufficiently so it does not melt together, yet later becomes rock through compression. See *welded tuff*.
ultraviolet radiation	Electromagnetic *radiation* with wavelengths from 4 to 400 nanometers. This range begins at the short wavelength limit of visible light and overlaps the wavelengths of long *x-rays* (some scientists place the lower limit at higher values, up to 40 nanometers). Also known as ultraviolet light.
uncanistered spent nuclear fuel	Commercial spent nuclear fuel placed directly into transportation casks. At the repository, DOE would remove spent nuclear fuel assemblies from the transportation cask and place them in a TAD canister before placement in a waste package or site aging overpack.
underground facility	In relation to the proposed *repository*, the underground structure, backfill materials, if any, and openings that penetrate the underground structure (for example, ramps, *shafts*, and *boreholes* and their seals).
unsaturated zone	The region between the surface and the water table where water fills only some of the spaces (fractures and rock pores).
vibration velocity decibels (VdB)	Vibration velocity in decibels with respect to 1 microinch per second. A measurement of root-mean-square velocity for the evaluation of ground vibration as an average or smoothed vibration amplitude on a logarithmic scale.
vitrification	A waste treatment process that uses glass (for example, *borosilicate glass)* to encapsulate or immobilize *radioactive* wastes.
waste package	Consists of the corrosion-resistant outer container, the waste form and any internal containers (such as the TAD canister), spacing structure or baskets, and shielding integral to the container. The waste package would be ready for emplacement in the repository when the outer lid welds were complete and accepted.

water table	1. The upper limit of the *saturated zone* (the portion of the ground wholly saturated with water). 2. The upper surface of a zone of saturation above which the majority of pore spaces and *fractures* are less than 100 percent saturated with water most of the time (*unsaturated zone*) and below which the opposite is true (saturated zone).
welded tuff	A *tuff* deposited under conditions where the particles that make up the rock were heated sufficiently to cohere. In contrast to nonwelded tuff, welded tuff is denser, less porous, and more likely to be fractured (which increases *permeability*).
Wet Handling Facility	A facility designed to handle uncanistered *commercial spent nuclear fuel* and to open and unload *dual-purpose canisters*; its essential purpose is to load TAD canisters.
wetland	• A shoreline or other area, such as a marsh or swamp, that is saturated with moisture, especially when it is the natural habitat of wildlife. • An area that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.
x-rays	Penetrating electromagnetic *radiation* with a wavelength much shorter than that of visible light. X-rays are identical to *gamma rays* but originate outside the *nucleus*, either when the inner orbital *electrons* of an excited atom return to their normal state or when a metal target is bombarded with high-speed electrons.
Yucca Mountain Repository (repository)	Inclusive term for all areas in the *Yucca Mountain site* where DOE would construct the proposed facilities to support the proposed repository, including roads.
Yucca Mountain site	The area inside the site boundary over which DOE has control. For the purpose of this *Repository* SEIS, Yucca Mountain site is synonymous with the *land withdrawal area.*
Yucca Mountain site boundary	That line beyond which DOE does not own, lease, or otherwise control the land or property for the purposes of the repository.
zirconium alloy	An alloy material that contains the element zirconium that can have several compositions. For this Repository SEIS, it is a *cladding* material.

13

Preparers, Contributors, and Reviewers

13. Preparers, Contributors, and Reviewers

13.1 Preparers and Contributors

This chapter lists the individuals who filled primary roles in the preparation of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). Jane R. Summerson, Ph.D., of the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management directed the preparation of the Repository SEIS. The Repository SEIS Team, lead by Joseph W. Rivers, Jr., of Jason Associates Corporation provided primary support and assistance to DOE; other members of the team include AGEISS Environmental, Inc., Dade Moeller & Associates, Inc., Tetra Tech NUS Inc., HRA Inc., and Battelle Memorial Institute.

DOE provided direction to the Repository SEIS Team, which was responsible for developing the analytical methodology and alternatives, coordinating the work tasks, performing the impact analyses, and producing the document. DOE was responsible for data quality, the scope and content of the Repository SEIS, and issue resolution and direction. The DOE Office of Civilian Radioactive Waste Management Technical Support Services contractor, Booz Allen Hamilton, assisted DOE in managing information flow and work priorities.

In addition, the Management and Operating contractor to the Office of Civilian Radioactive Waste Management (Bechtel SAIC Corporation and its subcontractors) assisted in the preparation of supporting documentation and information for this Repository SEIS, as did Sandia National Laboratories and the Nye County Nuclear Waste Project Office. These organizations, along with Potomac-Hudson Engineering, worked with the Repository SEIS Team to coordinate data and technologies for the simultaneous preparation of this Repository SEIS, the Rail Alignment EIS, and the application for an authorization to construct a repository.

DOE independently evaluated all supporting information and documentation prepared by these organizations. Further, DOE retained the responsibility for determining the appropriateness and adequacy of incorporating any data, analyses, and results of other work performed by these organizations in this Repository SEIS. The Repository SEIS Team was responsible for integrating such work in this Repository SEIS document.

As required by Federal regulations (40 CFR 1506.5[c]), Jason Associates Corporation and its subcontractors have signed *National Environmental Policy Act* (NEPA) disclosure statements in relation to the work they performed on this Repository SEIS. These statements appear at the end of this chapter.

Name	Education	Experience	Responsibility
		U.S. Department of Energy	
Jane R. Summerson	Ph.D., Geology, 1991 M.S., Geobiology, 1985 M.A., Anthropology, 1978 B.A., Anthropology, 1977	16 years – waste management projects with the DOE office of Civilian Radioactive Waste Management	DOE Document Manager
		Repository SEIS Team	
Joseph W. Rivers, Jr. Jason Associates Corporation	B.S., Mechanical Engineering, 1982	25 years – commercial and DOE nuclear projects, NEPA and regulatory compliance, systems engineering, and safety analysis.	Project Manager
Tonya Bartels AGEISS Environmental, Inc.	M.S., Analytical Chemistry, 1994 B.S. Chemistry, 1991	8 years – NEPA project support.	Lead Analyst: Land Use, Noise and Vibration, Aesthetics
Pixie Baxter Tetra Tech NUS Inc.	M.B.A., Economics, 1981 B.A., Art History	20 years – multidisciplinary economic and business experience including 15 years as economics college faculty member.	Lead Analyst: Socioeconomics
William J. Craig Dade Moeller & Associates	M.S., Planning, 1977 B.S., Forestry, 1972	27 years – power plant siting, nuclear fuel management, NEPA, project management, and public participation.	Lead Analyst: Similar Actions, Unavoidable Impacts, Appendix A; comment response team
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Name	Education	Experience	Responsibility
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Peter R. Davis Jason Associates Corporation	Oak Ridge School of Reactor Technology 1962 B.S., Physics, 1961	45 years – nuclear reactor and nuclear facility safety analysis and risk assessment.	Lead Analyst: Accident Scenarios
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Name	Education	Experience	Responsibility
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Steven Maheras Battelle Memorial Institute	Ph.D., Health Physics, 1988 M.S., Health Physics, 1985 B.S., Zoology, 1982 Certified Health Physicist, 1992	19 years – transportation risk assessment and radiological assessment, environmental and occupational radiation protection.	Lead Analyst: Transportation
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Name	Education	Experience	Responsibility
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Joanne Stover Jason Associates Corporation	B.S., Business Administration, 1996	20 years – technical editing, marketing, NEPA document development, and project management.	Production Team: document production manager, editor, document control, records, references
Julianne Turko AGEISS Environmental, Inc.	M.A., Geology, 1989 B.S., Geological Sciences, 1981	16 years – environmental compliance experience, NEPA, CERCLA, RCRA, CWA, CAA.	Lead Analyst: Cumulative Impacts
Christine Van Lenten Jason Associates Corporation	B.A., English, 1965	15 years – support to OCRWM/YMP and other DOE programs including WIPP and EM, principally as writer, editor, and policy analyst, handling broad range of subjects.	Summary

Name	Education	Experience	Responsibility
Susan Walker AGEISS Environmental, Inc.	Ph.D., Pathology, 1982 B.S., Zoology, 1975	32 years – toxicology, risk assessment, environmental studies including NEPA and regulatory compliance.	Deputy Project Manager; Document Manager; Lead Analyst: Environmental Justice
YuChien Yuan Jason Associates Corporation	Ph.D., Nuclear Engineering, 1976 M.S., Chemical Engineering, 1970 B. S., Chemical Engineering, 1967	31 years – radiological and health risk assessment, radionuclide transport and pathway analysis, occupational radiation protection.	Lead Analyst: Occupational and Public Health and Safety-radiological

13.2 Reviewers

The DOE Office of Civilian Radioactive Waste Management incorporated input to the preparation of this Repository SEIS from a number of other DOE offices that reviewed the document while it was under development. These include the offices of Environmental Management, Naval Reactors, Nuclear Energy, Materials Disposition, the National Spent Fuel Program, the National High-Level Waste Program, and General Counsel.

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ regulations at 40 CFR 1506.5(c), which have been adopted by DOE (10 CFR 1021), require contractors who will prepare an EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations," (46 FR 18026-18038 at Question 17a and b).

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)" (see 46 FR 18026-18031).

In accordance with these requirements, JASON ASSOCIATES CORPORATION hereby certifies it has no financial or other interest in the outcome of the project.

Certified By:

Signature

David Hoberg

Name (printed)

Vice-President/CFO

Title

Jason Associates Corporation

Company

September 5, 2007

Date

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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In accordance with these requirements, LECHEL, Inc. hereby certifies it has no financial or other interest in the outcome of the project.

Certified By:

David Lechel
Signature

DAVID LECHEL
Name (printed)

VICE PRESIDENT
Title

LECHEL, INC
Company

8-21-07
Date

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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In accordance with these requirements, AGEISS Environmental, Inc. hereby certifies it has no financial or other interest in the outcome of the project.

Certified By:

Donna Lawrence

Signature

Donna Lawrence

Name (printed)

President

Title

AGEISS Environmental, Inc.

Company

September 4, 2007

Date

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

Prime Contract No. DE-AM04-02AL67953
Task Order No. DE-AT28-06RW12374
Subcontract No. 1102S-0301

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In accordance with these requirements, Battelle Memorial Institute hereby certifies to the best of its knowledge and belief, it has no financial or other interest in the outcome of the project.

Certified By:

[signature]
Signature

Scott G. Williams
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Sr. Contract Administrator
Title

Battelle Memorial Institute – Columbus Operations
Company

September 6, 2007
Date

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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In accordance with these requirements, Dade Moeller & Associates hereby certifies it has no financial or other interest in the outcome of the project.

Certified By:

[signature]

Signature

Glenn S. Caprio

Name (printed)

Chief Operating Officer

Title

Dade Moeller & Associates

Company

9/4/07

Date

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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In accordance with these requirements, Tetra Tech NUS, Inc., hereby certifies it has no financial or other interest in the outcome of the project.

Certified By:

Signature

James L. Oliver
Name (printed)

Aiken Operations Manager
Title

Tetra Tech NUS, Inc.
Company

September 4, 2007
Date

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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In accordance with these requirements, AGEISS Environmental, Inc. hereby certifies it has no financial or other interest in the outcome of the project.

Certified By:

Signature

Heidi Roberts
Name (printed)

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Title

HRA Archaeology
Company

9-15-2007
Date

Draft

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

Volume II
Appendixes A through J

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250F-S1D

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TITLE: *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS).

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Information about this document is available on the Internet at the Yucca Mountain Project web site at http://www.ocrwm.doe.gov and on the DOE National Environmental Policy Act (NEPA) web site at http://eh.doe.gov/nepa/.

ABSTRACT: DOE's Proposed Action is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. Under the Proposed Action, spent nuclear fuel and high-level radioactive waste in storage or projected to be generated at 72 commercial and 4 DOE sites would be shipped to the repository by rail (train), although some shipments would arrive at the repository by truck. The Draft Repository SEIS evaluates (1) the potential environmental impacts from the construction, operation and monitoring, and eventual closure of the repository; (2) potential long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste; (3) potential impacts of transporting these materials nationally and in the State of Nevada; and (4) potential impacts of not proceeding with the Proposed Action (the No-Action Alternative).

COOPERATING AGENCIES: Nye County, Nevada is a cooperating agency in the preparation of the Repository SEIS.

PUBLIC COMMENTS: A 90-day comment period on this document begins with the publication of the Environmental Protection Agency Notice of Availability in the Federal Register. DOE will consider comments received after the 90-day period to the extent practicable. The Department will hold public hearings to receive comments on the document at the times and locations announced in local media and the DOE Notice of Availability. Written comments may also be submitted by U.S. mail to the U.S. Department of Energy at the above address in Las Vegas, via the Internet at http://www.ymp.gov, or by facsimile at 1-800-967-0739. This public comment period and the public hearings coincide with those of the *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada – Nevada Rail Transportation Corridor* (DOE/EIS-0250F-S2D; the Nevada Rail Corridor SEIS), and *Draft Environmental Impact Statement for a Rail Alignment for the Construction and Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0369D; the Rail Alignment EIS).

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Volume II

Appendix A

Options to Elements of the Proposed Action

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A. OPTIONS TO ELEMENTS OF THE PROPOSED ACTION

This is a new appendix since the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Waste at Yucca Mountain, Nye County, Nevada* (DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS) was completed. It describes options to elements of the Proposed Action presented in Chapter 2, Section 2.1 of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). It evaluates these options in terms of how the potential environmental impacts would differ from what the U.S. Department of Energy (DOE or the Department) anticipates from implementation of elements of the Proposed Action in Chapter 4, Section 4.1, and the Similar Actions in Section 4.3, of this Repository SEIS.

The options discussed in this appendix include:

- Wastewater treatment at the repository;
- Reduced transportation, aging, and disposal (TAD) canister use;
- National rail routes;
- Workforce residency; and
- Extended monitoring period.

This appendix provides insight to the extent potential impacts would be sensitive to modifications to the Proposed Action; for example, what is the situation if only 75 percent of commercial spent nuclear fuel could be placed in TAD canisters at commercial sites, with the remainder being loaded into TAD canisters at the repository.

A.1 Wastewater Treatment at the Repository Option

Chapter 2, Section 2.1.2.4.3, of this Repository SEIS acknowledges that under the Proposed Action, utility design does not specifically include a wastewater treatment facility; DOE could, however, develop one in the future to maximize the use of treated water. The current repository design includes septic tanks and leach fields for the treatment of sanitary sewage. A wastewater treatment facility would provide more options for industrial and sanitary wastewater, which would include the potential for reuse and recycling of the treated water. The following sections address the potential benefits and environmental impacts from a wastewater treatment facility.

If DOE implemented this option, it would use a premanufactured wastewater treatment facility. Such facilities are readily available and are in common use in small municipalities and on individual properties. A typical premanufactured wastewater treatment facility includes equipment for screening grit and solids, a compartment or tank for flow equalization, equipment and a tank for aeration to facilitate biological treatment of the main flow, clarification equipment, tanks for digestion of sludge separated from the main flow, and effluent disinfection (generally chlorination) equipment. Systems typically arrive as ready-to-connect modular components.

Nevada permits premanufactured wastewater treatment facilities with a minimum design flow of 19,000 liters (5,000 gallons) per day (Nevada Revised Statutes 445A.540). The facility must meet secondary treatment standards (DIRS 182842-NDEP n.d., all). If wastewater reuse became the option for effluent disposal, a state groundwater discharge permit would be necessary for any non-surface water discharges. DOE would dispose of wastewater discharge in excess of reuse needs to the surface by either a rapid infiltration pond or a leach field at the proposed repository.

A.1.1 POTENTIAL BENEFITS OF THE PREMANUFACTURED WASTEWATER TREATMENT FACILITY

A premanufactured wastewater treatment facility would enable wastewater reuse that the proposed septic systems would not offer. DOE could use the treated wastewater for dust suppression, landscaping, or other uses, thereby reducing the burden on the current once-through use of groundwater resources. For example, estimates of water demand for the Proposed Action (DIRS 181232-Fitzpatrick-Maul 2007, all) include a designation of up to about 25,000 cubic meters (20 acre-feet) of water per year for activities such as dust suppression. Treated wastewater could supplement a portion or possibly all of this demand. The flexible design of the facilities would enable the installation of additional modules to treat increases in wastewater volume. A treatment facility would offer the flexibility to accept industrial wastewater in addition to sanitary sewage.

A.1.2 POTENTIAL ENVIRONMENTAL IMPACTS OF THE PREMANUFACTURED WASTEWATER TREATMENT FACILITY

A premanufactured wastewater treatment facility would disturb no more land than the currently proposed septic tanks and leach fields. It would not affect air quality, biological resources, cultural resources, aesthetics, or noise. It would not affect surface- or groundwater resources differently than the currently proposed septic systems. However, there could be a positive impact through the treatment and reuse of water for activities such as dust suppression and landscaping. While there could be one or two additional employees as a result of installation of a wastewater treatment facility, there would be no additional socioeconomic impacts. Therefore, there would be no additional environmental impacts from the selection of a wastewater treatment facility over the currently proposed septic systems.

A premanufactured facility would require an initial outlay of capital that could be greater than that for construction of an additional conventional large-capacity septic system. In addition, a wastewater treatment facility would entail a higher level of regulatory compliance and monitoring in comparison to a conventional septic system; examples would include National Pollutant Discharge Elimination System permitting and monitoring, and increased monitoring of treated wastewater intended for reuse.

A.2 Reduced Transportation, Aging, and Disposal Canister Use Option

DOE’s goal under the Proposed Action (Chapter 2, Section 2.1.1) is the packaging of 90 percent of commercial spent nuclear fuel in TAD canisters at commercial sites. However, the sensitivity analysis in this appendix considers the potential case that only 75 percent of commercial spent nuclear fuel could be placed in TAD canisters at commercial sites, with the remainder placed in TAD canisters at the repository.

This Repository SEIS evaluates the potential environmental impacts of shipping nominally 90 percent [56,700 metric tons of heavy metal (MTHM)] of the commercial spent nuclear fuel in TAD canisters.

During the SEIS public scoping process, DOE received comments from the nuclear industry and others that asked what would happen if less than 90 percent of the commercial spent nuclear fuel arrived at the repository in TAD canisters. The following sections evaluate the difference in potential impacts if only 75 percent (47,250 MTHM) of the commercial spent nuclear fuel were shipped in TAD canisters and the remainder either in dual-purpose canisters or as uncanistered fuel. DOE would load uncanistered fuel and fuel that arrived at the repository site in nondisposable canisters into TAD canisters in the Wet Handling Facility.

This analysis evaluated the effects on transportation impacts and the estimated impacts at the repository. Differences in transportation impacts could result from differences in the number of transportation casks shipped. Consistent with the discussion Chapter 6 of this Repository SEIS, the transportation impacts would be associated with occupational and public health and safety. Differences in the impacts at the repository could result from the replacement of the third Canister Receipt and Closure Facility with a second Wet Handling Facility.

A.2.1 TRANSPORTATION IMPACTS

Table A-1 lists the amount of commercial spent nuclear fuel and the estimated number of transportation casks that DOE would transport and receive at the proposed repository for the nominal 90-percent case and the 75-percent case. In the 90-percent case, 88 percent of the commercial spent nuclear fuel would be shipped in rail casks containing TAD canisters, 5 percent would be shipped in rail casks containing dual-purpose canisters, and 7 percent would be shipped uncanistered in truck casks. These percentages are based on MTHM, not on the number of casks.

Table A-1. Comparison of commercial spent nuclear fuel transportation using 90-percent and 75-percent implementation of TAD canisters.

Transportation mode	Metric tons of heavy metal		Number of casks	
	90-percent case	75-percent case	90-percent case	75-percent case
TAD canister in rail cask	88.2	75.0	6,499	5,526
Dual-purpose canister in rail cask	4.8	4.8	307	310
Uncanistered spent nuclear fuel in rail cask	0.0	13.1	0	1,123
Uncanistered spent nuclear fuel in truck cask	7.0	7.1	2,650	2,666

Source: DIRS 181377-BSC 2007, all.
TAD = Transportation, aging, and disposal (canister).

In the 75-percent case, the amount of commercial spent nuclear fuel shipped uncanistered in truck casks and dual-purpose canisters in rail casks was held constant. The amount of commercial spent nuclear fuel shipped in rail casks containing TAD canisters was reduced from 88 percent to 75 percent. DOE assumed that the remaining 13 percent of commercial spent nuclear fuel would be shipped uncanistered in rail casks. As with the 90-percent case, these percentages are based on MTHM, not on the number of casks. Table A-4 of *Calculation of Transportation Data for SEIS Analyses* (DIRS 181377-BSC 2007, all) lists transportation cask fleet assumptions.

For both the 90- and 75-percent cases, DOE estimated that there would be about 8 transportation-related fatalities. These fatalities included latent cancer fatalities, fatalities from exposure to vehicle emissions, and traffic fatalities. Therefore, DOE concluded that a deviation in the percentage of implementation of TAD canisters at the reactor sites would not measurably affect the transportation impacts.

A.2.2 REPOSITORY IMPACTS

Nominally, 10 percent (6,300 MTHM) of the commercial spent nuclear fuel would require handling in the Wet Handling Facility. Under the 75-percent case, 25 percent (15,750 MTHM) of the commercial spent nuclear fuel would require handling in the Wet Handling Facility. This is an increase of 150 percent from the baseline case evaluated in Chapter 4 of this Repository SEIS. If fuel was not packaged in TAD canisters at the generator sites, it would be packaged at the repository and therefore would result in no changes in the long-term impacts or performance of the repository.

As stated above, the Department would construct an additional Wet Handling Facility rather than a third Canister Receipt and Closure Facility in the geologic repository operations area. Therefore, there would be no additional impacts to land use, air quality, biological and cultural resources, socioeconomics, noise, aesthetics, and utilities, energy, and materials.

Although the additional Wet Handling Facility would include a spent fuel pool for the underwater handling of fuel, the additional impacts to the estimated annual water demand would be minimal because DOE would closely monitor this pool, once filled, and the water would be continually filtered and maintained. The additional water demand from the new facility would be somewhat offset by the reduction in the number of Canister Receipt and Closure Facilities.

The additional spent fuel pool in the Wet Handling Facility would affect the management of repository-generated waste. DOE would treat the spent resins used to filter and maintain the chemistry of the pool as low-level radioactive wastes. The incremental increase in low-level radioactive waste from this source would be somewhat offset by the reduction in the number of Canister Receipt and Closure Facilities. Approximately 580 cubic meters (20,500 cubic feet) of low-level radioactive waste (including both solids and liquids before treatment) would be generated each year from a Wet Handling Facility in comparison with about 76 cubic meters (2,700 cubic feet) of low-level radioactive waste (including both solids and liquids before treatment) from a Canister Receipt and Closure Facility (DIRS 182319-Morton 2007, all).

Radiological impacts to workers would result primarily from external radiation from activities associated with the receipt, handling, aging, and emplacement of spent nuclear fuel and high-level radioactive waste. The reduction in the number of Canister Receipt and Closure Facilities would offset the external radiation impacts to workers from the additional Wet Handling Facility. The additional airborne release of manmade radionuclides would make virtually no contribution to the overall doses the repository workforce received.

Occupational and public health and safety would be the resource area most affected by the additional Wet Handling Facility. Airborne releases of manmade radionuclides during normal operations would occur only from the Wet Handling Facility. With two of these facilities to handle an increased (by 150 percent) inventory of commercial spent nuclear fuel, the releases of manmade radionuclides to the environment would also increase by 150 percent. Naturally occurring radon would account for more than 99.9 percent of the radiological impacts to the offsite public (Chapter 4, Section 4.1.7). The remainder (less than 1 percent) would be attributable to releases from the Wet Handling Facility. Therefore, an increase of 150 percent in these releases would have no measurable effect on impacts to the offsite public.

Consequences from accidents associated with the additional Wet Handling Facility would be the same as those identified in Chapter 4, Section 4.1.8, of this Repository SEIS for the original facility. The only effect the additional facility would cause would be an increase in the overall probability of the identified accidents because the number of activities (for example, crane lifts and fuel handling) would be greater. On the other hand, the number of associated activities that resulted in accidents in the Canister Receipt and Closure Facilities would decrease.

In summary, this analysis illustrated that the deviations in the percentage implementation of TAD canisters would have little effect on transportation or repository-related estimated impacts.

A.3 National Rail Route Option

DOE used the TRAGIS computer program to generate the representative rail routes it used to estimate the transportation impacts in Chapter 6 and Appendix G of this Repository SEIS. These rail routes are called unconstrained because constraints, or blocks, were not placed in the rail network. DOE based its identification of the representative national rail routes on historic railroad industry routing practices. The Department identified these routes by giving priority to the use of rail lines that have the most rail traffic, which are the best maintained and have the highest quality track; giving priority to originating railroads; minimizing the number of interchanges between railroads; and reducing the distance traveled.

Because DOE has not determined the rail routes it would use for the transportation of spent nuclear fuel and high-level radioactive waste to the repository and the routes would probably not be the exact representative routes identified by the TRAGIS program, this section provides a perspective on the sensitivity of the analysis to changes in the routing from the generator sites to the proposed repository. In addition, this analysis responds to the State of Nevada public scoping comment that “heavy traffic congestion along northern cross-country rail corridors will very likely make the southern routing option attractive.”

The purpose of this analysis was to evaluate the effects on the national transportation impacts if the TRAGIS computer program included constraints in the rail network that illustrate another way the railroads might route shipments. Based on preliminary discussions DOE has had with representatives of the railroad industry, stakeholder groups, and other interested parties, the routing modifications that were represented by constraints in the rail network were:

- A constraint on routing of spent nuclear fuel and high-level radioactive waste through long tunnels, such as the Moffat Tunnel west of Denver and the Flathead Tunnel in Montana.
- A constraint on use of the high-traffic Union Pacific rail line between North Platte and Gibbon Junction, Nebraska. This rail line currently handles about 130 trains per day and the presence of trains that contained spent nuclear fuel and high-level radioactive waste traveling at a maximum speed of 80 kilometers (50 miles) per hour would have the potential to disrupt railroad operations.
- A constraint on avoidance of major rail traffic congestion areas such as the Chicago rail yards.

This section contains national-level maps of the constrained routes and national-level impact estimates. As with the unconstrained routes, DOE used the TRAGIS program to generate these rail routes. Figures A-1 and A-2 show the constrained routes from each generator site to the repository using the Caliente and Mina rail corridors, respectively. For both the unconstrained and constrained cases on the national level, DOE estimated that there would be a total of about 8 transportation-related fatalities.

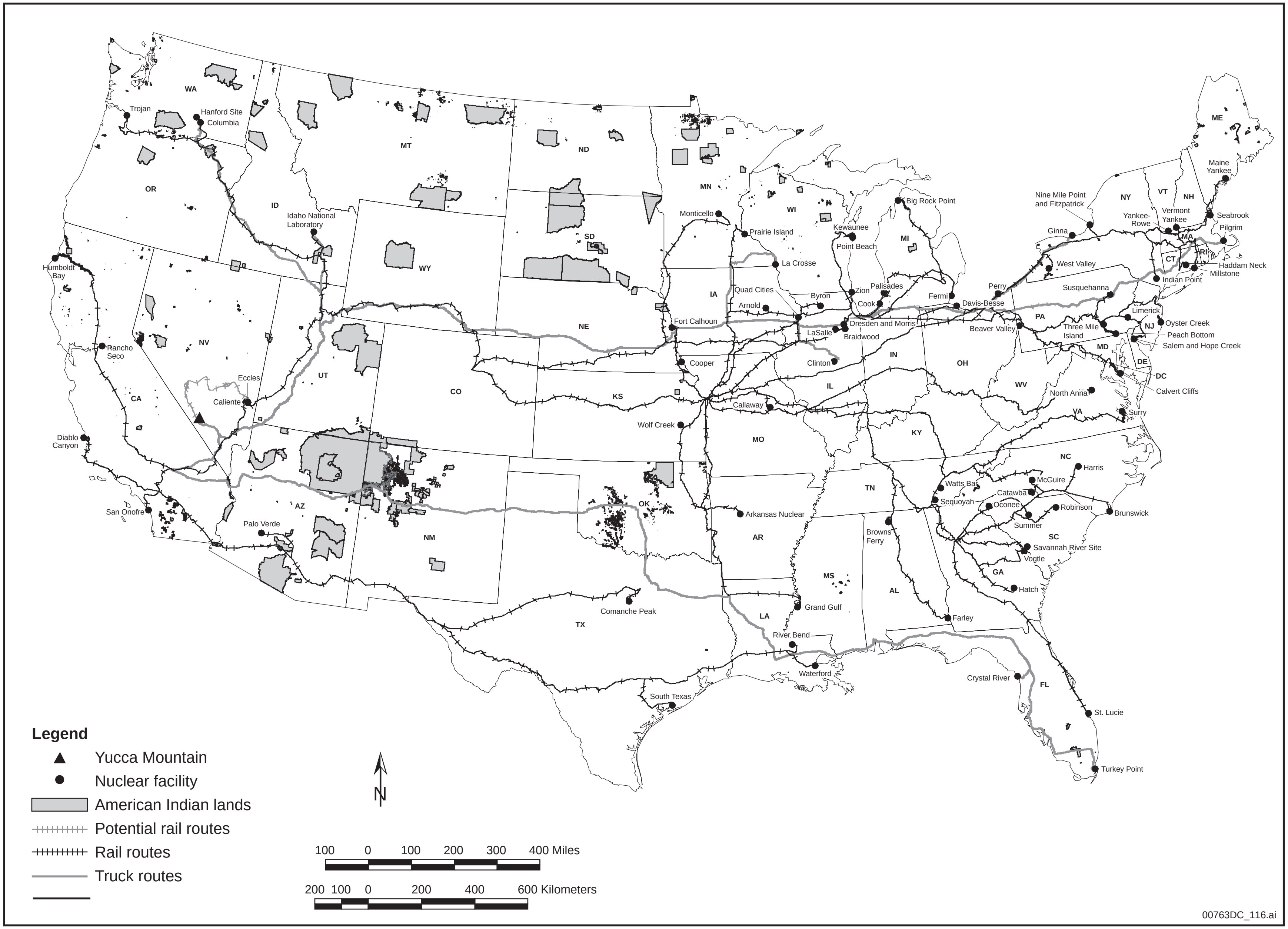


Figure A-1. Representative rail and truck transportation constrained routes if DOE selected the Caliente rail corridor in Nevada.

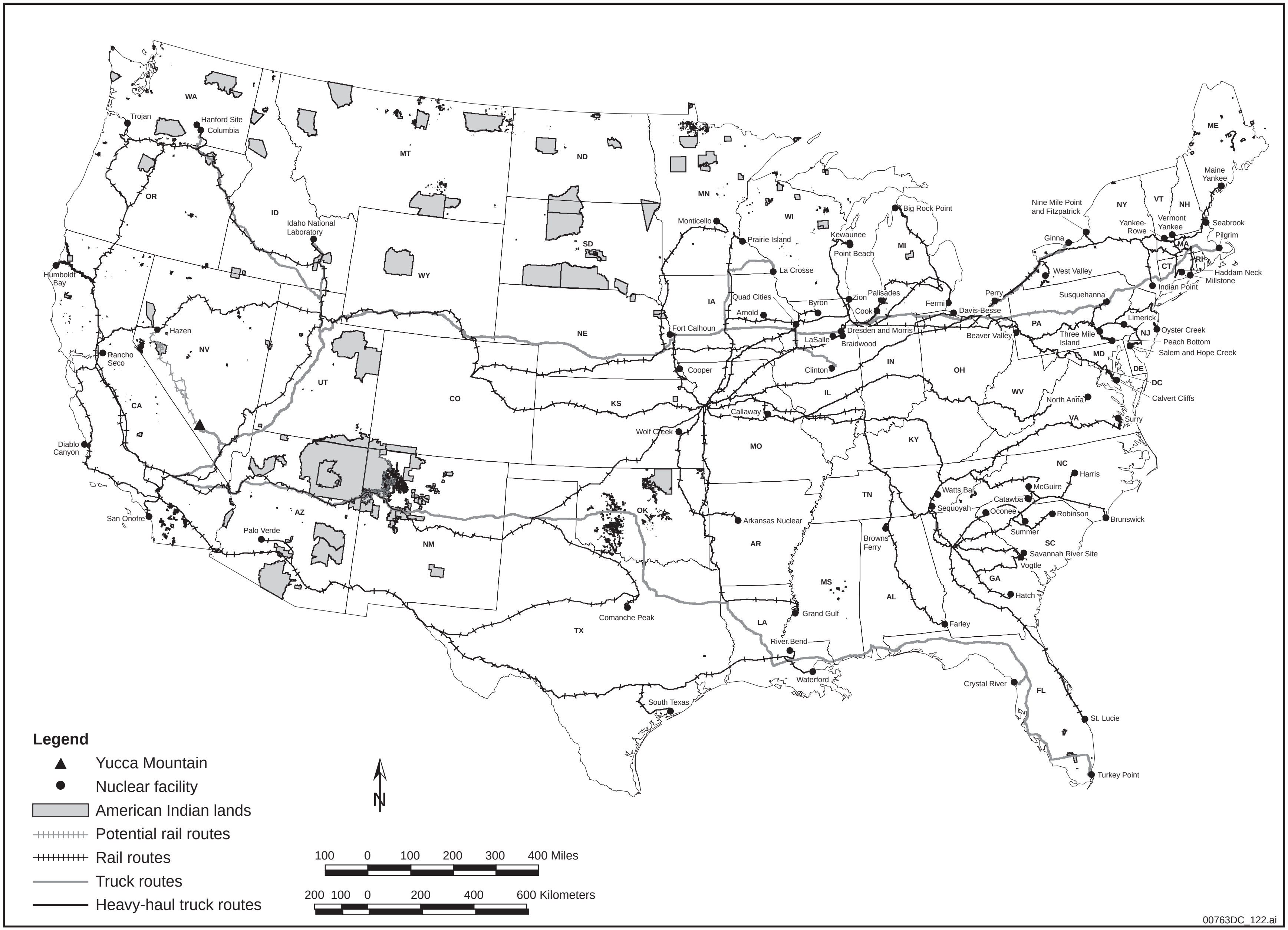


Figure A-2. Representative rail and truck transportation constrained routes if DOE selected the Mina rail corridor in Nevada.

These fatalities included latent cancer fatalities, fatalities from exposure to vehicle emissions, and traffic fatalities. DOE estimated that there would be 1 to 2 fatalities in Nevada for both the unconstrained and constrained cases. Therefore, DOE concluded that the use of constrained routing would not measurably affect transportation impacts.

A.4 Workforce Residency Option

This Repository SEIS evaluates socioeconomic impacts in Chapter 4, Section 4.1.6, and assumes that 80 percent of the onsite Yucca Mountain repository workers would reside in Clark County (Las Vegas). DOE based this assumption on historical data, which is consistent with the assumption it made for the analysis in the Yucca Mountain FEIS.

During the public scoping process for this Repository SEIS, DOE received comments from Nye County that requested evaluations of a higher percentage of the workforce that would reside in the county. For this analysis, this section provides an estimate of the potential socioeconomic impacts if 80 percent of the workforce assigned to the repository site, but none of the workforce assigned to offsite locations, resided in Nye County. While this percentage is not based on historical precedent like that in Chapter 4, Section 4.1.6, the analysis provides a perspective of the range of socioeconomic impacts that could occur. Uncertainties are becoming inherent in the historical patterns, given that certain factors that affect the current situation could affect future changes in ways different from those evaluated in the past. These factors include the increase in housing costs in Las Vegas due to large in-migration and the scarcity of land for development. In addition, in the future water issues could constrain development and further increase the cost of living in the Las Vegas Valley. These factors have already led to increased development in Nye County and outlying areas of Clark County. Because the majority of socioeconomic impacts would occur during the construction and operations periods, this sensitivity analysis addresses those periods. Impacts during the monitoring or closure period would be smaller because the workforce would be smaller.

The maximum of about 1,900 repository workers per year would make a small difference in the Las Vegas metropolitan area population of about 2 million. However, if a higher percentage of the onsite workers resided in Nye County, with a population of about 40,000, the socioeconomic impacts could be greater.

The worker residency option could result in increased traffic on U.S. Highway 95 in Nye County, particularly during the repository construction phase. Before construction, as described in Chapter 4, Section 4.3, DOE would move the access road southeast to coincide with the Nevada State Route 373 intersection and provide acceleration and deceleration lanes. Based on current projections of traffic volumes in the vicinity of the intersection, however, no additional actions would be required to maintain adequate levels of service prior to repository construction.

A.4.1 SOCIOECONOMIC IMPACTS

The evaluation in Chapter 4, Section 4.1.6 assumed that 80 percent of the proposed repository site workers would live in Clark County and included impacts to the State of Nevada. For this perspective analysis, DOE evaluated the impacts to the socioeconomic environment in Nye County under the assumption that 80 percent of the proposed repository site workers would live in Nye County (the 80-percent assumption). All other modeling parameters remained the same. The evaluation considered changes to employment, population, three economic measures (real disposable personal income, spending by state and local governments, and Gross Regional Product), housing, and some public services in Nye County. This perspective analysis focused on the impacts in the county. Because DOE estimated that the percentage of onsite workers who would live in Nye County would range between 20 and 80 percent, this discussion and that in Section 4.1.6 present bounding parameters of impacts in the county. This evaluation used the Regional Economic Models, Inc. model, *Policy Insight*, version 9, to estimate and project baseline socioeconomic conditions from 2012 to 2067 and to estimate employment and population changes due the Proposed Action. DOE prepared this alternative analysis of potential socioeconomic impacts as a result of scoping comments from Nye County. This analysis provides a perspective of the range of socioeconomic impacts that could occur. Because the majority of the socioeconomic impacts would occur during the construction and operations periods, this analysis addresses those periods.

A.4.1.1 Impacts to Employment

A.4.1.1.1 *Impacts to Employment During Construction*

Repository surface and subsurface construction would begin in 2012. In 2014, the peak year of direct project employment during the initial construction period, the Proposed Action would directly employ about 2,590 workers. About 1,860 of these workers, who would include approximately 220 current employees, would work at the repository site in Nye County. Workers employed during construction would include skilled craft workers and professional and technical support staff (engineering, safety analysis, safety and health, and others). Onsite employment during construction would peak during the last year of the construction period in 2016, with about 1,920 workers, as DOE transferred offsite positions and responsibilities from Clark County to the repository site.

Table A-2 lists the estimated direct project employment during the construction period. The direct onsite employment would increase by a factor of 4 from the current level of about 220 workers to about 1,000 at the beginning of the construction period and then to about 1,920 workers by the end of the construction period.

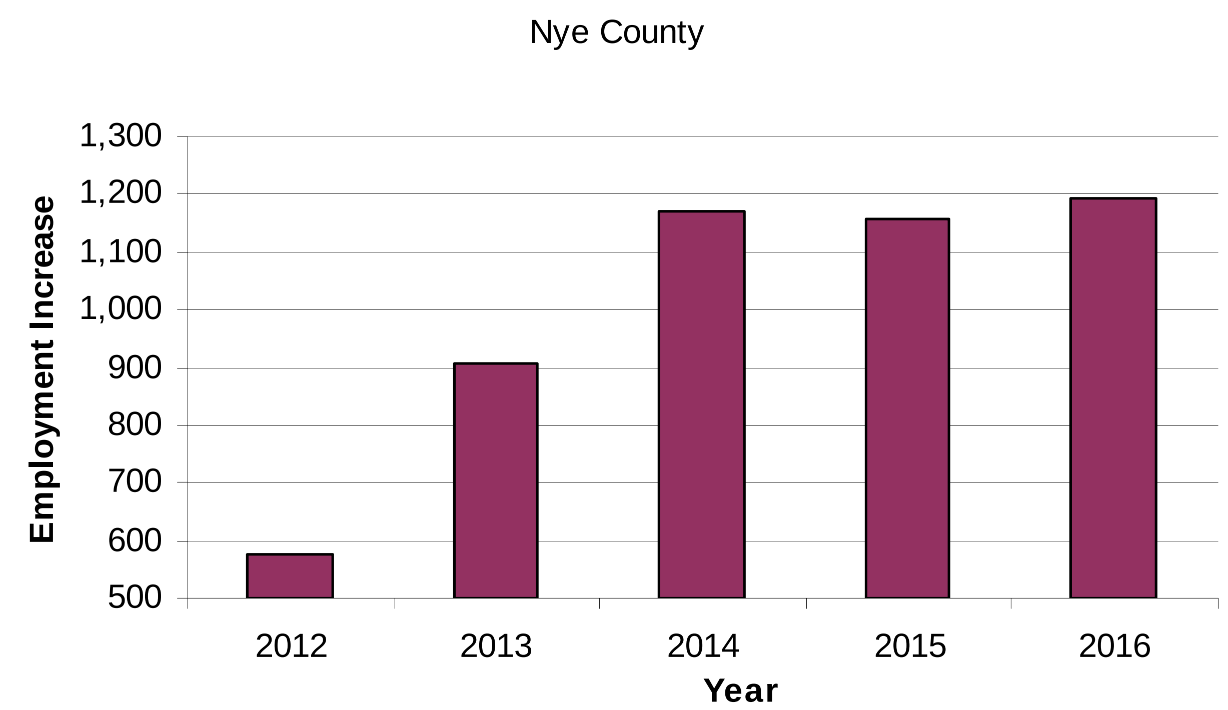
Table A-2. Direct project employment during construction, 2012 to 2016.

Employment	2012	2013	2014	2015	2016
Directly employed project workers[a] (onsite and offsite)	1,720	2,200	2,590	2,550	2,510
Directly employed repository site workers[a] (onsite only)	1,010	1,480	1,860	1,900	1,920

Source: DIRS 182205-Bland 2007, all.
Note: Numbers have been rounded to three significant figures.
a. Includes current workers.

During the construction period, the estimated employment baseline (number of jobs without the Proposed Action) in Nye County would grow from about 19,830 persons to about 20,820 persons. Because DOE believes the compensation packages for employment at the proposed repository would be very attractive, the analysis assumed some current Nye County workers would leave their current positions to join the repository workforce. Some of the vacated positions would not be filled because some jobs would be dissolved; others would remain unfilled. The *Policy Insight* model shows that, although the Yucca Mountain project would employ an additional 1,090 construction workers in 2014 (DIRS 182205-Bland 2007, all), this phenomenon could occur because, with construction of the repository, the average wage rate in the area would probably rise. Former sole proprietors and some county-based employers could elect to consolidate or eliminate abandoned positions rather than pay the higher wages necessary to attract replacement employees. Workers new to the labor force, the county, or the construction industry would fill some repository positions. Employment in the construction industry is constantly in flux and assignments begin and end in a relatively short period. Therefore, despite the new jobs at the repository, the number of composite jobs (direct and indirect) would be smaller than the number of direct repository jobs in Nye County during the construction period.

Figure A-3 shows changes in employment in Nye County during the construction period. During construction, about 580 to 1,190 new jobs or about 2.9 to 5.7 percent of the employment baseline in the county would result from repository construction. These impacts to employment would be large because they would be at or over 5 percent in 3 of the 5 years of construction. Most of the new jobs in the county would occur in the construction, professional and technical services, retail trade, and food and beverage industries.



Source: DIRS 182646-Bland 2007, all

Figure A-3. Changes in Nye County employment from repository construction activities, 2012 to 2016.

A.4.1.1.2 *Impacts to Employment During Operations*

Although the operations period would be from 2017 to 2067, most of the socioeconomic impacts would occur around 2020 in the early years of operations (in which subsurface construction would be concurrent with emplacement activities) and in 2040 when most subsurface construction activities would be complete. Because the years from 2020 to 2040 would be representative of the socioeconomic impacts from proposed activities during operations, the discussion focuses on these two decades.

Direct operations peak employment would occur near the beginning of the operations period when subsurface construction and emplacement activities occurred concurrently. In 2020, when repository operations would require about 2,590 workers, about 2,000 of these workers would work at the site in Nye County. Direct site employment would range from 2,000 to about 1,520 from 2020 to 2040, and then would be essentially stable with an average of about 560 workers until 2067. The Proposed Action would contribute jobs to the Nye County economy during the entire construction period. The incremental increase in jobs would be about 1,700 jobs in 2020, 1,800 jobs in 2030 and 1,650 jobs in 2040. The number of jobs would decline as DOE completed emplacement activities. Figure A-4 shows the incremental increases over the county employment baseline during the operations period.

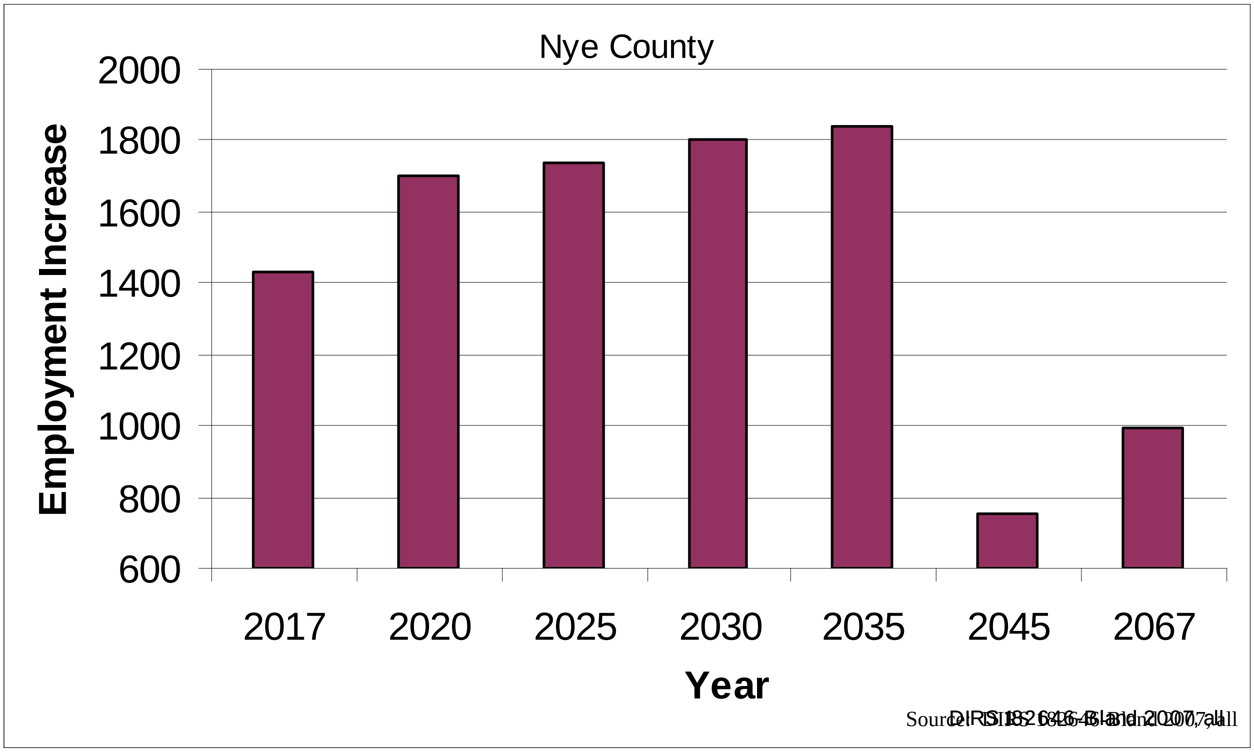


Figure A-4. Changes in Nye County employment from repository operations, 2017 to 2067.

Direct employment would create many indirect jobs if 80 percent of the onsite workforce lived in Nye County because the county employment base is small and not able to provide the additional goods and services workers and their families would need without the creation of additional capacity; that is, more new capacity would be required. The Proposed Action would contribute jobs to the Nye County economy during the entire operations period. Incremental changes in population would be smaller than changes in employment because current residents of the county or family members of the directly employed workers (rather than in-migrants) would fill many of the indirect jobs that resulted from the direct employment.

In 2020, Nye County would gain about 1,700 jobs. The change in the number of jobs would be substantial and represent an almost 8-percent acceleration of job growth over the baseline in the county for that year. From 2020 until 2040, job growth in Nye County without the repository would average about 1 percent each year; with the repository, the average annual growth rate would be 1.3 percent (almost a third more quickly). The Nye County estimated employment baseline for 2020 is 21,700 jobs. With the repository, the number of jobs would increase to 23,400 in 2020 (1,700 new jobs added to the 21,700 baseline jobs—jobs that would be in the county without the proposed action—for a total of 23,400 jobs). In 2040, the baseline number of jobs would be 26,300 and the number of additional repository jobs, 1,650, would mean a total of 27,950 jobs in the county. Generally, the number of baseline jobs in a county grows over time as it does here – from 21,700 in 2020 to 26,300 in 2040. Employment in years 2040 and 2041 is very similar, and repository employment after 2040 is too small to affect the county as noted in the text. The narrative focuses on the 20-year period when the repository employment impacts the county, 2020 to 2040. Table A-3 lists the baseline and the changes in employment for 2020 to 2040 in Nye County. Although the operations period would extend beyond 2040, onsite employment and, therefore, impacts would decline after 2040. By 2042, the impacts to employment would decline to below 3 percent over the baseline.

Table A-3. Changes in Nye County employment from repository activities in operations period, representative years.

Change	2020	2025	2030	2035	2040
Incremental change[a]	1,700	1,740	1,800	1,840	1,650
Baseline employment[a]	21,700	22,600	23,700	24,900	26,300
Percent change over baseline[b]	7.9	7.7	7.6	7.4	6.3

Source: DIRS 182646-Bland 2007, all.

a. Numbers have been rounded to three significant figures.

b. Percentages have been rounded to two significant figures.

The change in the rate of job growth during operations would be pronounced. Most of the new jobs from the first 25 years of the operations period would be professional and technical services positions, followed by federal civilian service positions, retail trade positions, jobs in food and beverage places, and local government jobs. The construction industry would have a decreasing presence as the operations period advanced.

A.4.1.1.3 *Summary of Employment Impacts*

Under the 80-percent assumption, impacts on employment in Nye County would be large (greater than 5 percent over the baseline) for the first 30 years of construction and operations and then small (less than 3 percent over the applicable baselines). The repository would be Nye County’s largest employer.

A.4.1.2 Impacts to Population

Incremental changes in population due to repository employment would largely be the result of the choice of county of residence that workers and their families made. Changes in population would lag changes in employment by several years.

A.4.1.2.1 *Impacts to Population During Construction*

Without the Proposed Action, Nye County’s estimated baseline population would grow from 55,800 to 62,300 people during the construction period years. With the 80-percent assumption, the Proposed Action would result in an incremental increase in population in Nye County that grew steadily from about 81 persons in 2012 to 560 persons in 2016; these increases would be about 0.15 to 0.9 percent of the county’s population baseline, which would be small. In part, the increase in population would be small because many construction workers would live in temporary worker camps and, therefore, would not become part of the permanent census of the county.

A.4.1.2.2 *Impacts to Population During Operations*

In general, increases in population would lag increases in employment by several years because some workers would delay relocation. Because the labor force in Nye County is small, many operations workers who would live in Nye County would be new to the county. As a result of repository activities, in 2040 about 4,120 additional people, a change of 4.6 percent over the county's baseline population of 90,100 in that year, would live in Nye County, which would be a moderate impact. State and local government agencies would need to adjust levels of service to accommodate the increase in population. Unlike the temporary nature of increases during the construction period, increases in population from repository activities during operations would be relatively permanent. The impact to population over the baseline would be moderate at first—3 to 5 percent from 2020 until 2040—and then it would decline to just below 3 percent. The repository would have a defining presence on the population in Nye County. Private-sector providers would need to consider the effects of the repository in their strategic plans. Figure A-5 shows the projected population increases from the repository in Nye County during the operations period. Increases in population would result in impacts to housing and public services (Sections A.4.1.4 and A.4.1.5, respectively). Without the repository, Nye County's population would grow at an average annual rate of 1.4 percent; under the 80-percent assumption for this analysis, the county would grow at an average annual rate of 1.7 percent.

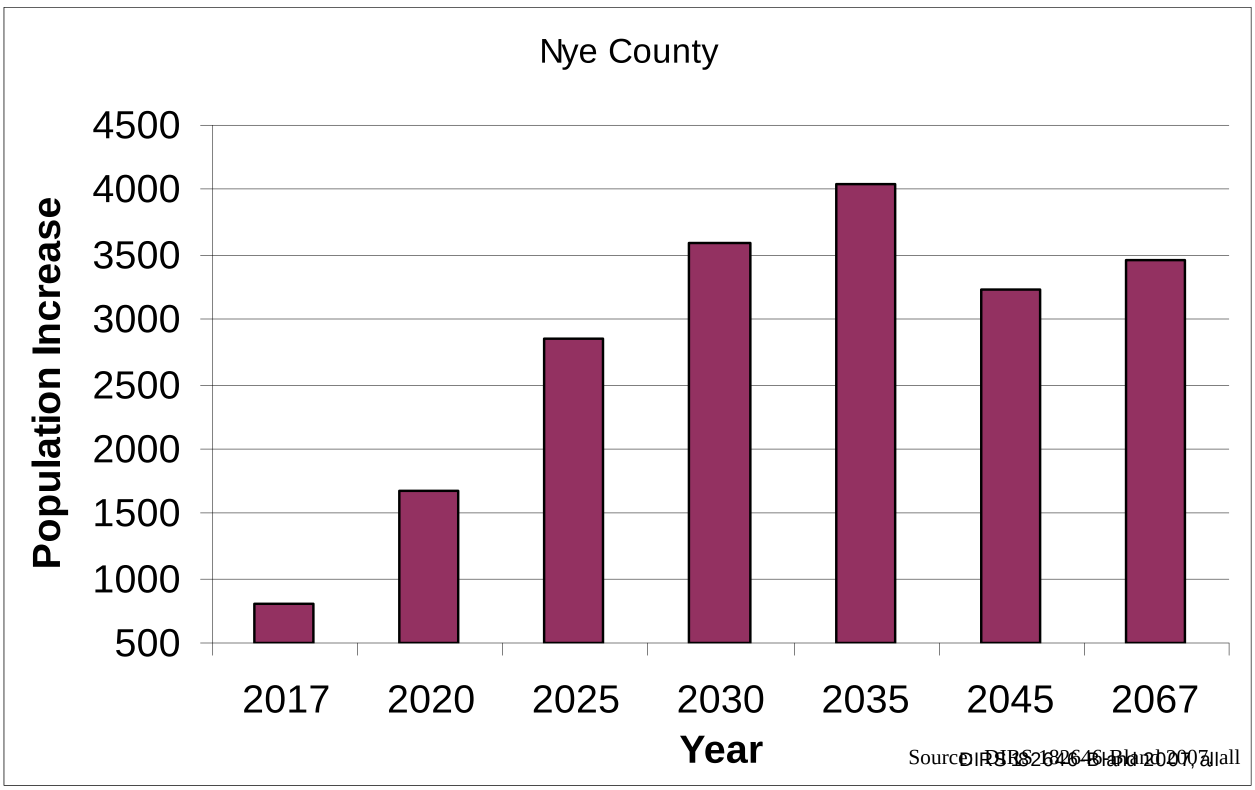


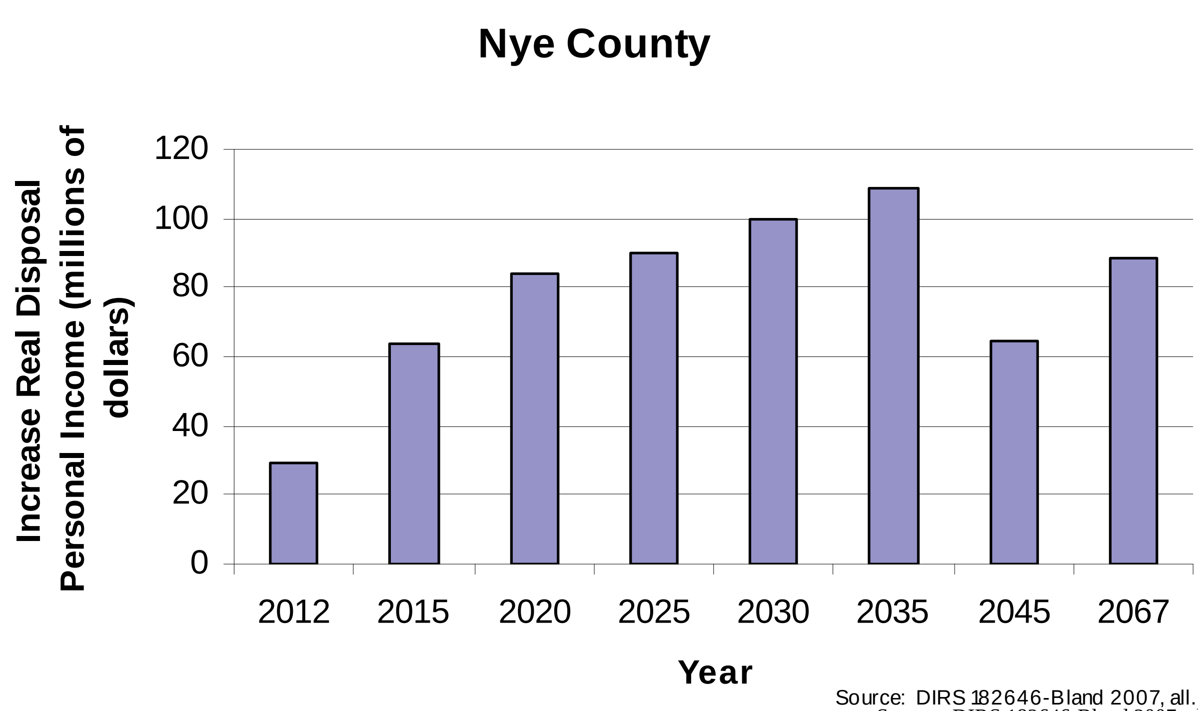
Figure A-5. Changes in Nye County population from repository operations, 2017 to 2067.

A.4.1.3 Impacts to Economic Measures

This section discusses changes in economic measures in Nye County that would result from repository activities during the construction and operations periods. (Values are in 2006 dollars.)

A.4.1.3.1 *Impact to Economic Measures During Construction*

Increases in real disposable personal income (after-tax income) in the county would peak in 2016 with an increase of about $65.7 million under the 80-percent assumption, which would be a moderate increase of 4.5 percent over the baseline of $1.47 billion. During the construction period, the increase in real disposable personal income would result primarily from onsite worker wages. In 2016, per capita (per person) real disposable personal income would increase by about $800 to $24,600. Figure A-6 shows information about changes in real disposable personal income for the construction and operations periods.



Source: DIRS 182646-Bland 2007, all

Figure A-6. Changes in real disposable personal income in Nye County during construction and operations periods, 2012 to 2067.

During the construction period, increases in Gross Regional Product in Nye County would peak at the end of the construction period at about $86.9 million or about 5.4 percent of the baseline. The increase would occur as retailers and the service industry escalated efforts to produce goods and services for repository workers and other residents of Nye County. The county would produce some repository construction products (for example, concrete and tools), and those sales would be a part of the increases in Gross Regional Product. Per capita Gross Regional Product would grow by an addition $1,200. Figure A-7 shows estimated changes in Gross Regional Product for the construction and operations periods.

Changes in expenditures by the State of Nevada and local governments in Nye County during construction would peak at $2.4 million, a small change of less than 1 percent over the baseline. These changes would result from small incremental population increases during construction. Spending by state and local governments would be primarily from revenues from sales of goods and services. Per capita expenditures by state and local governments would increase very slightly, about $10. Figure A-8 shows estimated changes in spending by state and local governments for the construction and operations periods.

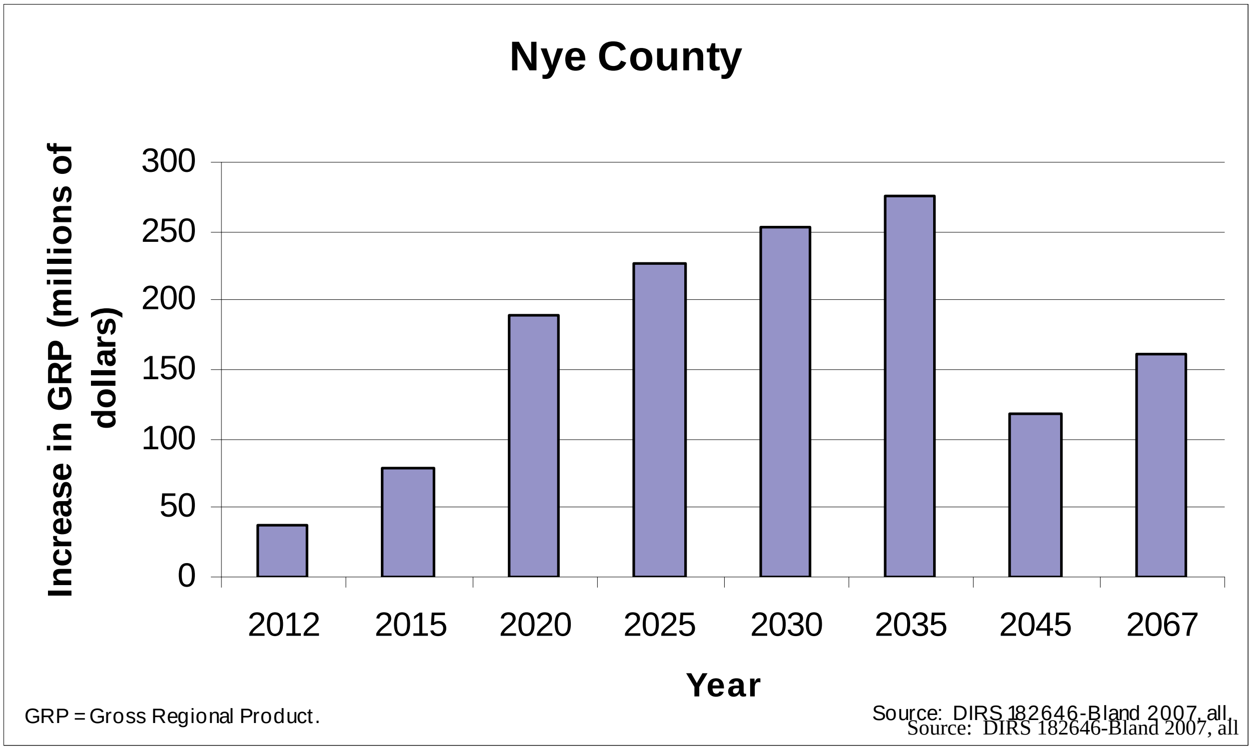


Figure A-7. Changes in Gross Regional Product in Nye County from repository activities during construction and operations periods, 2012 to 2067.

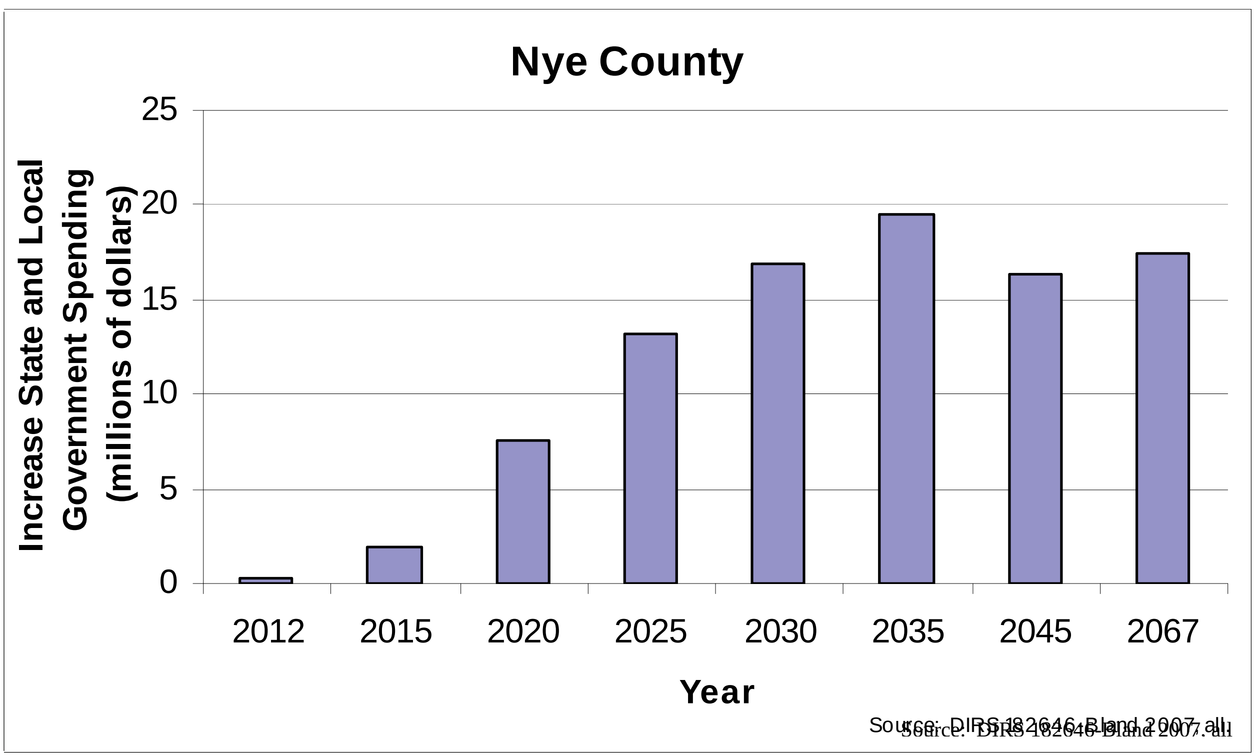


Figure A-8. Changes in spending by state and local governments in Nye County from repository activities during construction and operations periods, 2012 to 2067.

During construction, Nye County would experience moderate to large increases over the Gross Regional Product baseline and small to moderate changes in real disposable personal income over the baseline. Impacts to state and local government spending would be small—less than 1 percent.

A.4.1.3.2 *Impacts to Economic Measures During Operations*

As with employment and population, the years from 2020 to 2040 would be the most representative of socioeconomic impacts from repository operations. Nye County would experience a large impact from two economic measures during operations: Gross Regional Product and real disposable personal income. Figures A-6 to A-8 show the changes in economic measures in Nye County that would result from the repository project during the construction and operations periods under the 80-percent assumption.

During the operations period, the impact of changes in real disposable personal income would be proportionally greater than during construction because this economic measure more fully captures wages earned by directly and indirectly employed workers. Most operations workers would make Nye County their permanent home and spend the majority of their earnings in the county. Increases in real disposable personal income would be large from 2020 to 2040. Impacts over the baseline would range from 5.2 percent in 2020 to 4.3 percent in 2040. The impact after that would be small, less than 3 percent. Increases in real disposable personal income would range form $83.9 million in 2020 to about $106.5 million in 2040. Repository workers who lived in Nye County would spend most of their wages in the county and in turn create income for the providers of goods and services. Economic activity, which would include incidental spending by workers who lived in Clark County but worked in Nye County, would be responsible for this phenomenon. In addition, many indirect jobs and the income from those jobs would remain in Nye County. In 2020, repository activity would result in per capita real disposable personal income growing from the baseline $23,720 to $24,360. Figure A-6 shows information about changes in real disposable personal income for the construction and operations periods.

Nye County would experience an increase from $189.5 million in 2020 to $260.4 million in 2040 in Gross Regional Product, an increase of 10.5 to 8.6 percent, respectively, over the baseline. These would be large impacts. The Gross Regional Project would increase as repository workers and their families demanded and consumed goods and services and area businesses met the demand by providing the desired products. Gross Regional Product is an important variable used to determine an area's economic health. The repository-related increase in Gross Regional Product coupled with the large impact to real disposable personal income would confirm the county's economic viability. Impacts to Gross Regional Product would remain moderate from about 2040 to 2067. Figure A-7 shows changes in Gross Regional Product for the construction and operations periods.

Spending by the State of Nevada and local governments in Nye County would increase by $7.5 million or 2.6 percent of the baseline in 2020 and by $20.4 million or 4.8 percent in 2040. Nye County could spend tax and marginal revenues (revenue sources that originate outside the county such as the Payments-Equal-to-Taxes provisions) from increased economic activity associated with the repository. Figure A-8 shows changes in spending by state and local government for the construction and operations periods. Much of the spending could be due to the incremental increase in population from the repository. Throughout the operations period, the Proposed Action would have almost no impact on per capita spending by state and local governments. In 2020, per capita baseline spending by state and local government would be $4,305. Construction and operation of the repository would increase per capita spending by state and local governments by $15.

During operations, impacts to real disposable personal income and Gross Regional Product would generally be large. Impacts to spending by state and local governments would generally be moderate.

A.4.1.3.3 *Summary of Impacts to Economic Measures*

Under the 80-percent assumption, impacts from repository-related activities in Nye County would be more pronounced during the operations period as workers and families established residency and spent earnings. Business activity would increase due to the production of goods and services to meet resident demands. Other businesses would produce increased goods and services to provide products for repository operations. As a result, the largest affected economic measure would be Gross Regional Product.

A.4.1.4 Impacts to Housing

Nye County and more specifically Pahrump have recently experienced rapid and largely unanticipated growth, and the county has a limited housing inventory for absorption of new workers and worker families. However, because the estimated incremental increases in population during construction would be small, the increased demand for housing would also be small. Many construction workers would live in temporary construction camps and not need additional housing.

Nye County would experience small to moderate increases in population when operation activities began. As a result of repository activities under the 80-percent assumption, as many as 4,120 additional people would live in Nye County in 2040. This would be an increase of 4.6 percent over the population baseline of 90,100 residents in that year. Because of its proximity to the proposed repository site, much of the additional demand for housing could concentrate in Pahrump. Demands on the county’s specific housing inventory available at that time should be small to moderate because housing stock generally increases at approximately the same rate the population increases. Nye County would experience a rate of population growth of approximately 1.4 percent annually even without the Proposed Action. However, the impact to housing could be moderate, rather than small, because (1) the demand should be concentrated in Pahrump, which is currently managing very rapid growth (more rapid than the county as a whole), and (2) although there are no local or state growth control measures that limit housing development, water rights are increasingly scarce.

Nye County has an adequate supply of undeveloped land to meet expected future demands. The incremental increase in population from repository-related activities would occur over a long period and be predictable, so the private sector housing market could readily adapt. In addition, the county has demonstrated concern about future growth and has taken action to acquire land and prepared plans for a comprehensive live-work community to facilitate and accommodate the orderly development of land use that repository activities could trigger.

Nye County has also acquired land to facilitate and accommodate the orderly development of land uses that repository activities could trigger. The county’s infrastructure system, particularly in Pahrump, is currently strained and at capacity. In addition, the desert setting of the county means developers are dependent on water rights, which are crucial to development. With a very limited supply of water and a rapidly growing population, the ability of the private or public sector to meet housing demands remains speculative. Unless infrastructure systems, including water rights, can expand, adequate housing supply for anticipated growth could be compromised.

Although the need for additional housing in Nye County can readily be predicted, the resolution of water right issues and infrastructure funding issues could be much more protracted.

DOE analyzed potential impacts to housing at the county rather than the community level. The Department did not attempt to predict incremental housing demand at the community level because housing preferences (mobile home, modular assembly, stick-built), density or cluster choices (single family, multifamily), and desired lot sizes are difficult to predict.

A.4.1.5 Impacts to Public Services

The moderate repository-related increases in population in Nye County could cause impacts to public services. Southern Nye County, particularly Pahrump, would experience increased demand for public services. However, because the changes in population in the county would occur steadily over a long period and result in increases in government revenues, the county would be able to plan for and absorb increased demands for education and public safety services such as law enforcement and fire protection. These services are currently at capacity. Nye County communities are geographically widely separated from one another, and communities cannot readily share public services. If the incremental population increases reflected the current patterns in Nevada (rather than Nye County, which has a large retirement-age population), about 21 percent of new residents in a year would be school-age children. Schools in Nye County are at capacity, and the county is widely reliant on portable units at present. The county and the communities in the county would continue to provide services as the government revenue base grew.

Gross Regional Product would increase with repository activities. Under the 80-percent assumption, the increase in Nye County would be very large—approximately 10 percent when repository operations began. The large impact to Gross Regional Product would result in tax revenue for local and state sources. Nevada collects sales tax of 6.75 percent (except on groceries). There is no corporate, personal, unitary, inventory, or franchise tax in the state or in Nye County, so wages and business profits would not directly benefit the coffers of state and local governments. Pahrump has the lowest property tax assessment of the county's local jurisdictions. As increased earnings drove the increases in real disposable personal income, businesses would rally to provide more goods and services to meet the increased demand. The purchase of some goods and services due to repository construction and operations would occur from county-based vendors. Under the 80-percent assumption, these increases would be noticeable because the impacts would represent a large percentage increase rather than a large absolute increase. DOE facilities have historically had cooperative agreements with local governments for mutual aid and support of emergency services. DOE implementation of such an agreement in conjunction with the Proposed Action would reduce strains on regional emergency services infrastructure. Repository-related impacts to public services could require mitigation because the impacts would probably be community-specific rather than county-wide and because the unincorporated communities would have little ability to generate tax revenue for public services. The recently opened 24-bed hospital in Pahrump, along with the ample services available in metropolitan Las Vegas, could serve to alleviate the scarcity of medial services in Nye County.

A.4.1.6 Summary of Socioeconomic Impacts During Construction and Operations

If 80 percent of the repository site workers lived in Nye County, there would be meaningful, measurable socioeconomic impacts in the county from construction and operations. The greater impacts would be long-term and would occur during the operations period. Repository-related incremental changes in employment in Nye County would generally be large during construction because the workforce at the repository would represent such a big portion of the county's current job base. The changes over the baseline in Gross Regional Product would be large because county businesses would respond to the demand for additional goods and services. Incremental changes in population during construction would be small because most construction workers would not relocate to Nye County with their families but would live in temporary work camps and return to out-of-county homes on the weekends. Changes in state and local spending would be small because agencies would not need to provide additional services for small, temporary increases in population. Increases in real disposable personal income would be moderate as the estimated 1,000 to 1,900 onsite project workers earned wages. The increases in real disposable personal income and Gross Regional Product would result in a more vibrant economy and generally would be beneficial. The increase in employment would result in increases in population, which in turn would cause the economy to grow. Growth in population can strain public services, and increases in population can change the ambiance of an area.

Nye County would experience larger socioeconomic impacts during repository operations than during construction. Incremental changes in population and spending by state and local government would be moderate in the operations period—generally 3 to 5 percent over the baselines. Changes in employment and real disposable personal income would generally be large—from 5 to almost 8 percent. Changes to the county's Gross Regional Product would be even larger—more than 10 percent over the baseline. However, public services are currently at capacity. Repository-related impacts to public services could require mitigation because the unincorporated communities would have little ability to generate tax revenue for public services.

A.5 Extended Monitoring Period

Chapter 2, Section 2.1.2 of this Repository SEIS describes the four analytical periods for the Proposed Action. For purposes of analysis in this Repository SEIS, monitoring and closure activities would end 50 years after the emplacement of the last waste package. The 10-year closure period would overlap the last 10 years of monitoring activities. Chapter 4, Section 4.1 presents the estimated environmental impacts for monitoring and closure activities during the 50-year timeframe. However, DOE could extend the monitoring period an additional 200 years (that is, ending 250 years after the emplacement of the last waste package). This section presents the potential additional environmental impacts that could occur as the result of an extended monitoring period beyond the initial 50 years of monitoring.

A.5.1 ENVIRONMENTAL IMPACTS OF EXTENDED MONITORING

DOE anticipates that several environmental resource categories would not have any continued impacts due to extended monitoring, or would have impacts the same as those during the initial 50 years of monitoring. In the cases of *cultural resources* and *aesthetics*, the impacts would have already been rendered and, to the extent necessary, mitigated. New cultural resources or scenic areas would be unlikely to become of interest. In the case of *socioeconomics*, the workforce associated with extended monitoring would be so small it would not be perceptible in the regional or state economy. In relation to *environmental justice*, DOE concluded in Chapter 4, Section 4.1.13.3 that, based on the analyses performed, "no disproportionately high and adverse impacts would result from the Proposed Action." In terms of *accidents*, no new scenarios or accident categories would be applicable to extended monitoring. Impacts from *noise* would not differ from those during the initial 50-year monitoring period. There would be some noise from ventilation fans, compressors, and other machinery if DOE maintained them beyond the first 50 years of monitoring. The distances to the site boundaries would be unlikely to change.

The following sections discuss the potential additional environmental impacts of monitoring an additional 200 years after emplacement of the last waste package and repository closure.

A.5.1.1 Land Use and Ownership

As discussed in Chapter 4, Section 4.1.1.1, withdrawal of lands for repository purposes would prohibit public use of the lands. Extended monitoring would extend the unavailability of the withdrawn lands for other uses.

A.5.1.2 Air Quality

Chapter 4, Section 4.1.2.3 of this Repository SEIS presents impacts to air quality from monitoring. The analysis concluded that because surface construction, subsurface excavation, and subsurface emplacement activities would be complete, emissions would probably be substantially lower from those listed in Table 4-3. This conclusion would also apply to the extended monitoring period.

A.5.1.3 Hydrology

Chapter 4, Section 4.1.3.2.3 of this Repository SEIS states that "water demand during the monitoring and closure periods would be lower and of less concern and would be expected to remain as presented in the Yucca Mountain FEIS." The estimated water requirement for monitoring activities is 7,400 cubic meters (6 acre-feet) per year and would be unlikely to change during the extended monitoring period.

A.5.1.4 Biological Resources and Soils

The potential impacts to biological resources and soils due to an extended monitoring period would be smaller than those DOE described in Chapter 4, Section 4.1.4 of this Repository SEIS. DOE does not anticipate additional land disturbance during the extended monitoring period that could add to disrupted or fragmented habitat; the greatly reduced workforce and level of site activities would result in a decrease in the deaths of individual species due to traffic and human activity.

A.5.1.5 Occupational and Public Health and Safety

Potential nonradiological health and safety impacts to workers would occur from industrial hazards and exposure to naturally occurring cristobalite and erionite. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring hazardous materials and criteria pollutants.

From a radiological health and safety standpoint to workers, potential impacts would come from exposure to naturally occurring and manmade radiation and radioactive materials. There could also be exposure to members of the public from airborne releases of naturally occurring and manmade radionuclides.

A.5.1.5.1 *Nonradiological Impacts*

Chapter 4, Section 4.1.7.1.3 of this Repository SEIS describes nonradiological health impacts during monitoring. The analysis assumed that the heath and safety impacts to workers for the monitoring period would be similar to those described in the Yucca Mountain FEIS. With an extended monitoring period, DOE anticipates that industrial hazard impacts for all workers would increase as follows:

Total recordable cases:	1,000 additional
Lost workday cases:	420 additional
Fatalities:	0.95 additional

From the standpoint of potential exposure to cristobalite and erionite, extended monitoring activities would be unlikely to generate large quantities of dust, and there should be reduced potential for exposure.

Potential impacts to member of the public would be unlikely from naturally occurring hazardous materials or criteria pollutants because construction would be complete and there would be fewer emissions in comparison to previous periods.

A.5.1.5.2 *Radiological Impacts*

The principal contributor to radiological health impacts to workers would be from subsurface facility monitoring and maintenance activities that DOE could conduct during the extended monitoring period. Potential radiological health impacts to the public from monitoring activities could result from exposure to releases of naturally occurring radon-222 and its decay products in subsurface exhaust ventilation air.

Table A-4 lists the radiological impacts from 200 years of extended monitoring.

Table A-4. Radiological impacts from 200 years of extended monitoring.

Occupational and public health and safety		Impact for additional 200-year monitoring period[a]
Public, Radiological		
MEI (probability of an LCF)	0.00029	No change
Population (LCFs)	8	18
Fatalities due to emissions		
Workers (involved and noninvolved)		
Radiological (LCFs)	4.4	2.8

a. Additional impacts were obtained by multiplying the 40-year monitoring impacts by a factor of 5 (200 divided by 40).
LCF = Latent cancer fatality.

A.5.1.6 Utilities, Energy, Materials, and Site Services

The extended monitoring period would result in the continued consumption of energy in terms of electricity use and the consumption of fossil fuel, oils, and lubricants. There would be no additional consumption of construction materials. Table 4-29 in Section 4.1.11 lists estimates for the use of electricity and fossil fuels. The following estimates represent continued consumption of materials for the extended monitoring period:

Electricity use:	12.6 million megawatt-hours (based on 63,000 megawatt-hours per year) additional
Fossil fuel:	210 million liters (55.5 million gallons) additional
Oils and lubricants:	44 million liters (11.6 million gallons) additional

A.5.1.7 Waste and Hazardous Materials

During the extended monitoring period, DOE could continue to generate sanitary sewage, low-level radioactive waste, and sanitary and industrial waste. DOE does not anticipate the generation of hazardous waste or industrial wastewater. The Department assumed that the disposition of each waste stream would continue as described in Chapter 4, Section 4.1.12 of this Repository SEIS. The following are the estimated volumes of waste that DOE would generate during the extended monitoring period:

Sanitary sewage:	656,000 cubic meters (858,000 cubic yards)
Low-level radioactive waste:	13.000 cubic meters (17,000 cubic yards) (includes solids and liquids)
Sanitary and industrial waste:	52,000 cubic meters (68,000 cubic yards)

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Appendix B

Nonradiological Air Quality

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B. NONRADIOLOGICAL AIR QUALITY

Potential releases of nonradiological pollutants during the construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository could affect the air quality in the surrounding region. This appendix discusses the methods, data, and intermediate results DOE used to estimate impacts from potential nonradiological releases to air for this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). Chapter 4, Section 4.1.2, presents results for the Proposed Action.

Nonradiological pollutants can be categorized as hazardous and toxic air pollutants, criteria pollutants, or other substances of particular interest. Repository activities would cause the release of no or small quantities of hazardous and toxic pollutants; therefore, the U.S. Department of Energy (DOE or the Department) did not consider these pollutants in the analysis. The National Ambient Air Quality Standards (40 CFR Part 50), which were established by the *Clean Air Act*, regulate concentrations of six criteria pollutants. This analysis quantitatively evaluated releases and potential impacts of four of these pollutants—carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter. Particulate matter has two categories: $PM_{2.5}$, particulate matter with an aerodynamic diameter of 2.5 micrometers or less (about 0.0001 inch), and $PM_{10,}$ particulate matter with an aerodynamic diameter of 10 micrometers or less (about 0.0004 inch). Sources of $PM_{2.5}$ include smoke, power plants, and gasoline and diesel engines; sources of PM_{10} include dust and gasoline and diesel engine exhaust emissions. The analysis considered the two other criteria pollutants—lead and ozone. It also considered potential releases to air of cristobalite, a form of crystalline silica that can cause silicosis and is a potential carcinogen. Erionite, an uncommon zeolite mineral, could be encountered during underground construction, but it appears to be absent or rare at the proposed repository depth and location. Erionite would not affect air quality in the area around the repository and was not considered in the analysis. Releases of these pollutants could occur during all project analytical periods.

Section B.1 discusses the regulatory limits for criteria pollutants and cristobalite. Section B.2 discusses the models and computer programs DOE used to estimate impacts to nonradiological air quality, and Section B.3 describes the selection of maximally exposed individuals and their locations. Section B.4 discusses meteorological data and reference concentrations of pollutants for analysis. Sections B.5 through B.7 describe the sources of pollutants and the impacts to air quality for the proposed repository construction period, the operations and monitoring periods, and the closure period, respectively. Section B.8 describes the sources of pollutants and the impacts to air quality from construction and operation of the proposed railroad and associated facilities.

B.1 Regulatory Limits

Table B-1 lists the six criteria pollutants that the U.S. Environmental Protection Agency (EPA) and the State of Nevada regulate under the National Ambient Air Quality Standards or the Nevada Administrative Code along with their regulatory limits and the periods during which DOE averaged pollutant concentrations. The criteria pollutants that this section of the appendix addresses quantitatively are nitrogen dioxide, sulfur dioxide, particulate matter (both PM_{10} and $PM_{2.5}$), and carbon monoxide. Because there would be no sources of airborne lead at the repository, the analysis did not consider that

Table B-1. Criteria pollutants and regulatory limits.

Pollutant	Averaging period	NAAQS regulatory standards: Parts per million	NAAQS regulatory standards: Micrograms per cubic meter	Nevada standards
Nitrogen dioxide	Annual	0.053	100	Same
Sulfur dioxide	Annual	0.03	80	Same
	24-hour	0.14	365	Same
	3-hour[a]	0.5	1,300	Same
Carbon monoxide	8-hour	9	10,000	Same[b]
	1-hour	35	40,000	Same
PM_{10}	24-hour		150	Same
$PM_{2.5}$	Annual		15	None
	24-hour[c]		35	None
Ozone	8-hour	0.08		None
	1-hour[d]	0.12	235	Same
Lead	Quarterly		1.5	Same

Sources: 40 CFR Part 50 and Nevada Administrative Code 445B.22097.

a. Secondary standard.

b. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 5,000 feet above mean sea level and 6 parts per million at or above 5,000 feet.

c. Effective December 17, 2006.

d. Applies only to the 14 8-hour ozone nonattainment Early Action Compact Areas. Does not apply at Yucca Mountain.

NAAQS = National Ambient Air Quality Standards.

pollutant. The purpose of the ozone standard is to control the ambient concentration of ground-level ozone rather than the naturally occurring ozone in the upper atmosphere. Ozone is not emitted directly into the atmosphere; rather, it is created by complex chemical reactions of precursor pollutants in the presence of sunlight. The precursor pollutants are volatile organic compounds and nitrogen oxides (including nitrogen dioxide).

DOE's analysis of ozone evaluated the emissions of these precursors. The major source for volatile organic compounds and nitrogen dioxide is the burning of fossil fuels. The maximum annual fuel use under the Proposed Action would be about 1.1 percent of the total diesel fuel use and about 0.021 percent of the total gasoline use in Nevada in 2004. Because about half of the State of Nevada fossil-fuel consumption is in the three-county region of Clark, Lincoln, and Nye counties (DIRS 155970-DOE 2002, p. 4-76), the maximum annual fuel use under the Proposed Action would be about 2.2 percent of the diesel fuel and about 0.04 percent of the gasoline use in those three counties in 2004. The peak annual release of volatile organic compounds from the burning of fossil fuels would occur during the first 5 years of the operations period and would be about 13,700 kilograms (30,000 pounds) (Section B.6). Because Yucca Mountain is in an attainment area for ozone, the analysis compared the estimated annual release of volatile organic compounds to the Prevention of Significant Deterioration of Air Quality emission threshold for volatile organic compounds for stationary sources (40 CFR 52.21). The peak annual release would be well below the emission threshold of 36,000 kilograms (80,000 pounds) per year. The maximum annual concentration of nitrogen dioxide at the boundary of the land withdrawal area from the burning of fossil fuels during the operations period would be about 0.11 percent of the regulatory limit. The annual emissions would be about 10 percent of the total estimated nitrogen dioxide emissions of 1.3 million kilograms (1,400 tons) in Nye County during 2002 (DIRS 177709-EPA 2006, all). About 80 percent of the existing Nye County nitrogen dioxide emissions are the result of on-road automobile and truck sources. Emissions of nitrogen dioxide due to the Proposed Action would be relatively small in comparison to the existing yearly emissions in Nye County. DOE anticipates that the impact of the ozone precursors, volatile organic compounds and nitrogen dioxide, would not cause violations of the ozone standard.

EPA revised the air quality standards for particulate matter in 2006 (40 CFR Part 50). For $PM_{2.5}$, the 2006 standards tightened the 24-hour regulatory limit from 65 to 35 micrograms per cubic meter and retained the annual regulatory limit at 15 micrograms per cubic meter. For PM_{10}, the 2006 standards retained the 24-hour regulatory limit of 150 micrograms per cubic meter but revoked the annual PM_{10} standard. EPA revoked this standard because available evidence does not suggest a link between long-term exposure to PM_{10} and health problems. The new standards took effect on December 17, 2006.

Cristobalite, one of several naturally occurring crystalline forms of silica (silicon dioxide), is a major mineral constituent of Yucca Mountain tuffs (DIRS 155970-DOE 2002, p. G-2). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Further, the World Health Organization lists crystalline silica as a *carcinogen*. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations. This discussion incorporates by reference Appendix F, Section F.1.2 of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Yucca Mountain FEIS) (DIRS 155970-DOE 2002, pp. F-12 to F-14), which contains additional information on crystalline silica.

There are no limits for exposure of the general public to cristobalite. Consistent with the analysis in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. G-3), the analysis for this Repository SEIS used a comparative benchmark of 10 micrograms per cubic meter based on a cumulative lifetime exposure calculated as 1,000 micrograms per cubic meter multiplied by years. At this level, an EPA health assessment (DIRS 103243-EPA 1996, pp. 1-5 and 7-5) states that there is a less than 1-percent chance of silicosis. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter, which DOE rounded down to 10 micrograms per cubic meter to establish a more conservative benchmark (DIRS 155970-DOE 2002, p. G-3). Additional studies of occupational exposure to respirable crystalline silica, which used higher concentration levels, have produced results that are consistent with the EPA health assessment. These studies predict that approximately 1 to 7 silicosis cases per 100 workers would occur at respirable quartz concentrations of 25 micrograms per cubic meter (DIRS 176528-CDC 2002, p. 24). This concentration was 2.5 times the benchmark level. Because the studies have shown that doubling the concentration of respirable dust can produce greater than four times the incidences of silicosis (DIRS 176528-CDC 2002, p. 25), the prediction of 1 to 7 silicosis cases per 100 workers is consistent with the EPA health assessment.

Exposure to cristobalite to members of the public and to surface workers could occur. The sources of cristobalite releases would include fugitive dust from the excavated rock pile and dust emission from subsurface excavation via exhaust ventilation. Fugitive dust from the rock pile would be the larger source. DOE would perform evaluations of airborne crystalline silica at Yucca Mountain during routine operations and tunneling. For this analysis, DOE assumed that 28 percent of the fugitive dust from the rock pile and from subsurface excavation would be cristobalite, which reflects the cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Use of the parent rock percentage overestimates the airborne cristobalite concentration; studies of both ambient and occupational airborne crystalline silica have shown that most of this airborne material is coarse and not respirable and that larger particles deposit rapidly on the surface (DIRS 103243-EPA 1996, p. 3-26).

B.2 Computer Modeling and Analysis

DOE used the American Meteorological Society/EPA Regulatory Model (AERMOD) computer program, version 07026, to estimate the annual and short-term (24-hour or less) air quality impacts at the proposed repository. The Yucca Mountain FEIS used the Industrial Source Complex (ISC) computer model to estimate air quality impacts. The change in models occurred because EPA established AERMOD as the preferred air dispersion model in place of the ISC model (40 CFR Part 51, Appendix W). The AERMOD provides better characterization of plume dispersion than the ISC model. The regulation became effective December 9, 2005.

The AERMOD model is a state-of-the-practice Gaussian plume dispersion model for assessment of pollutant concentrations from a variety of sources. It simulates transport and dispersion from sources by using an up-to-date characterization of the atmospheric boundary layer. The model uses hourly sequential preprocessed meteorological data to estimate concentrations for averaging times that range from 1 hour to 1 year. The program is appropriate for simple or complex terrain, and for urban or rural environments (40 CFR Part 51). It can handle multiple sources that include point, volume, and area source types. Users can model line sources as elongated area sources and define multiple receptor locations. The analysis used the AERMOD Terrain Preprocessor (AERMAP), version 06341, to prepare terrain inputs for AERMOD. AERMOD used two meteorological files during its calculations: one file defined surface boundary layer parameters, and the second defined profile variables such as wind speed, wind direction, and turbulence parameters. The AERMOD meteorological preprocessor (AERMET), version 06341, generated these meteorological inputs, which are from hourly National Weather Service surface meteorological data, twice-daily upper air data, and local surface meteorological data (DIRS 181091-EPA 2004, all).

Because DOE based the short-term pollutant concentrations on annual use or release parameters, conversion of annual parameter values to short-term values depended on the duration of the activity. The Department assumed that many repository activities would have a schedule of 250 working days per year, so the daily release would be the annual value divided by 250.

In many cases, site- or activity-specific information was not available for estimates of pollutant emissions at the Yucca Mountain site. In these cases, DOE used generic information and made conservative assumptions that tended to overestimate actual air concentrations.

Chapter 4, Section 4.1.2, summarizes total nonradiological air quality impacts for the Proposed Action. Consistent with the analysis established in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-3 and G-4), the impacts are the sum of air quality impacts from individual sources and activities that would occur during each analyzed project period. Individual sources and activities are described in Sections B.5 to B.7. The maximum air quality impact (that is, maximum criteria pollutant concentration) from individual sources or activities could occur at different locations around the analyzed land withdrawal area boundary, depending on the release period and the regulatory averaging time (Section B.4). These maximums would generally occur in a westerly or southerly direction due to the prevailing winds in the area. The total nonradiological air quality impacts in Section 4.1.2 are the sum of the calculated maximum concentrations regardless of direction. Therefore, the values are larger than the actual sum of the concentrations would be for a particular distance and direction. DOE selected this approach to simplify the presentation of air quality results and produce the most conservative results.

B.3 Locations of Exposed Individuals

DOE determined the locations of the public hypothetically exposed individuals by calculating the maximum ground-level pollutant concentrations. Because the public would have access only to the site boundary, the analysis followed the methodology that DOE established in Appendix G of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-1 to G-44) and assumed that a hypothetical individual would be present at one point on the site boundary during the entire averaging time of the regulatory limit (Table B-1).

Table B-2 lists the approximate distances from the North and South Portals to the analyzed land withdrawal area boundary, where the analysis evaluated maximally exposed individual locations. The table does not list all directions because the land withdrawal area boundaries would not be accessible to members of the public in some directions (restricted access areas of the Nevada Test Site and the Nevada Test and Training Range). The distance to the nearest unrestricted public access in these directions would be so large that there would be no air quality impacts to the public. For the east to south-southeast directions, the distances to the land withdrawal area boundary would be large, but the terrain is such that plumes that traveled in these directions tend to enter Fortymile Wash and turn south. The southern land withdrawal area boundary would be the location of a maximally exposed individual with long-term (1-year) unrestricted access, such as a resident. The short-term (1- to 24-hour) maximally exposed individual location could be the western land withdrawal area boundary, the potential location of an individual such as a hiker or hunter. No long-term access (that is, residency) could occur at this location on government-owned land. The analysis based the evaluated access periods on the exposure periods in Table B-1.

Table B-2. Distance to the nearest point of unrestricted public access (kilometers).

Direction	From North Portal	From South Portal
Northwest	14	15
West-northwest	12	12
West	11	11
West-southwest	14	12
Southwest	18	16
South-southwest	23	19
South	21	18
South-southeast	21	19
Southeast	22	24

Source: Derived from DIRS 104493-YMP 1997, all, and DIRS 153849-DOE 2001, p. 1-21.
Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

The potential location of the maximally exposed individual member of the public for surface construction outside the analyzed land withdrawal boundary would not be at the boundary of the area. The maximally exposed person would be adjacent to the offsite construction. The analysis assumed that this individual would be 100 meters (330 feet) from the construction activities. Although 40 CFR Part 51, Appendix W does not specify an optimum receptor location, a fence line around the construction activity or the distance to the nearest building or residence is often assumed to be the closest possible location for a member of the public. Because DOE can only approximate the exact locations of construction activities and the distances to the surrounding fence lines at this time, the analysis used the approximate distance (100 meters) between existing buildings and U.S. Highway 95 as the distance between construction activities and the maximally exposed individual.

B.4 Meteorological Data and Reference Concentrations

DOE used the AERMOD computer program to estimate the concentrations of the criteria pollutants in the region of the repository. The simulations used surface and upper air meteorological data from the National Weather Service station at Desert Rock, Nevada, and onsite surface meteorological data from the meteorological station at Fortymile Wash (YMP 5). DOE used meteorological station YMP5 for AERMOD simulation because the analysis calculated emission concentrations not only for activities at the repository surface facilities but also for additional activities within the analyzed land withdrawal area and for construction activities outside the land withdrawal area. Meteorological station YMP5 would best represent the meteorological data for all activities within and outside the land withdrawal area. The most recent meteorological data that are readily available to the public for Desert Rock, Nevada, are for 1984 to 1992. DOE was able to assemble a 4-year meteorological record for 1987, 1988, 1989, and 1990 of hourly data from both the National Weather Service and the onsite meteorological station. Those data were preprocessed with AERMET for input into AERMOD.

Desert Rock is near Mercury, Nevada, approximately 44 kilometers (27 miles) east-southeast of the proposed North Portal surface facilities. DOE used surface meteorological data from the Desert Rock station in the analysis because of its complete hourly weather data, which include cloud cover and ceiling height. This information was not available for climate stations at Yucca Mountain. DOE used the onsite data from Yucca Mountain for site-specific temperature, relative humidity, wind direction, wind speed, and precipitation.

The analysis used the methodology in Section G.1.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-5 and G-6) and estimated unit release concentrations at the land withdrawal area boundary points of maximum exposure for ground-level release sources. The concentrations were based on release rates of 1 gram (0.04 ounce) per second for each of the five regulatory limit averaging times (annual, 24-hour, 8-hour, 3-hour, and 1-hour). Activities at the Yucca Mountain site during the construction period could result in releases of pollutants over four periods in a 24-hour day [continuously, 8 hours, 12 hours (two 6-hour periods), and 3 hours]. Eleven combinations of release periods and regulatory limit averaging times would be applicable to activities at the Yucca Mountain site.

The analysis assumed that the 8-hour pollutant releases would occur from 8 a.m. to 4 p.m. and would be zero for all other hours of the day. Similarly, it assumed that that the 3-hour pollutant releases would occur from 9 a.m. to 12 p.m. and would be zero for all other hours. The 12-hour release would occur over two 6-hour periods, assumed to be from 9 a.m. to 3 p.m. and from 5 p.m. to 11 p.m.; other hours would have zero release. Continuous releases would occur throughout the 24-hour day. The estimates of all annual average concentrations assumed the releases were continuous over the year.

Table B-3 lists the maximum unit release concentrations for the 11 combinations of the site-specific release periods and regulatory limit averaging times. The AERMOD analysis used the meteorological

Table B-3. Unit release concentrations (micrograms per cubic meter based on a release of 1 gram per second) for maximally exposed individual locations for 11 combinations of four release periods and five regulatory limit averaging times.

Release	South Portal development area	Surface geologic repository operations area and vicinity	Other locations in land withdrawal area (including access road and Gate 510)
Continuous–annual average concentration	0.025	0.027	0.0053
Continuous–24-hour average concentration	1.6	1.2	0.10
Continuous–8-hour average concentration	3.7	2.7	0.31
Continuous–3-hour average concentration	6.9	4.6	0.82
Continuous–1-hour average concentration	21	10.	2.5
8-hour (8 a.m. to 4 p.m.) – 24-hour average concentration	0.86	0.41	0.10
8-hour (8 a.m. to 4 p.m.) – 8-hour average concentration	2.6	1.2	0.31
8-hour (8 a.m. to 4 p.m.) – 3-hour average concentration	6.9	3.1	0.82
8-hour (8 a.m. to 4 p.m.) – 1-hour average concentration	21	9.2	2.5
12-hour (9 a.m. to 3 p.m. and 5 p.m. to 11 p.m.) – 24-hour average concentration	1.1	0.82	0.087
3-hour (9 a.m. to 12 p.m.) – 24-hour average concentration	0.19	0.38	0.087

Note: Numbers are rounded to two significant figures.

data during a single year from 1987 through 1990 that would result in the highest unit concentration to estimate the unit concentrations and directions. Table B-3 lists the 24-hour averaged concentration for the 3- and 12-hour release scenarios because the activities of these scenarios would release only PM_{10}, which has a 24-hour regulatory limit.

Table B-3 lists the maximum unit release concentrations for activities at the South Portal development area and the surface geologic repository operations area and vicinity. The other locations represent construction activities that include the main access road, primary roads, borrow pits, and infrastructure power lines in the land withdrawal area.

Table B-4 lists the unit release concentrations for construction outside the analyzed land withdrawal area near the access road intersection with U.S. Highway 95. It represents activities that include a U.S. Highway 95 intersection, an offsite Sample Management Facility, and other disturbed land outside the land withdrawal area. DOE calculated the unit release concentrations at 100 meters (330 feet) from the construction activity (Section B.3). The emissions from this location would primarily be criteria pollutants from the burning of fossil fuel and PM_{10} from disturbed land.

Using the unit release concentration information listed in Tables B-3 and B-4, DOE calculated the estimated criteria pollutant concentrations for each source or activity (that is, the air quality impact) by multiplying the maximum unit release concentration for each averaging period by the estimated source release rate. DOE chose the maximum unit release concentration regardless of receptor direction or source location (that is, South Portal, North Portal, or other onsite location) because this is the most

Table B-4. Unit release concentrations (micrograms per cubic meter based on a release of 1 gram per second) and direction to maximally exposed individual location for receptors 100 meters from surface construction activities outside the land withdrawal area.

Release	Direction from construction	Unit release concentration outside land withdrawal area
Continuous – annual average concentration	South	13
Continuous – 24-hour average concentration	South	82
Continuous – 8-hour average concentration	South	170
Continuous – 3-hour average concentration	South	300
Continuous – 1-hour average concentration	South	860
8-hour (8 a.m. to 4 p.m.) – 24-hour average concentration	East	27
8-hour (8 a.m. to 4 p.m.) – 8-hour average concentration	South	73
8-hour (8 a.m. to 4 p.m.) – 3-hour average concentration	East	200
8-hour (8 a.m. to 4 p.m.) – 1-hour average concentration	South	580
12-hour (9 a.m. to 3 p.m. and 5 p.m. to 11 p.m.) – 24-hour average concentration	South	50
3-hour (9 a.m. to 12 p.m.) – 24-hour average concentration	South	4.7

Note: Numbers are rounded to two significant figures.

conservative approach. The following sections describe the source release rates and impacts for each period of activity.

B.5 Construction Period

This section describes the methods DOE used to estimate air quality impacts during the construction period. The Department would begin construction of surface facilities and would complete sufficient excavation of the subsurface to support initial emplacement activities during this period.

Consistent with the methodology in Appendix G of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-1 to G-44), this analysis used calculations of the pollutant concentrations from various construction activities at the proposed repository to determine air quality impacts. To calculate impacts, DOE multiplied the estimated pollutant emission rates by the maximum unit release concentration for each averaging period (Section B.4). This produced the pollutant concentration for comparison to regulatory limits. The Department estimated short-term pollutant emission rates and concentrations using the method described in Section B.2.

The principal emission sources of PM_{10} would be fugitive dust from construction activities on the surface, excavation of rock from the repository, storage of material in the excavated rock pile, and dust emissions from concrete batch facilities. The principal sources of carbon monoxide, nitrogen dioxide, sulfur dioxide, and $PM_{2.5}$ would be fuel combustion in construction equipment and other surface vehicles. The following sections describe these sources in more detail.

B.5.1 FUGITIVE DUST EMISSIONS FROM SURFACE CONSTRUCTION

Construction activities such as earth moving and truck traffic would generate fugitive dust. For this analysis, and consistent with the methodology in the Yucca Mountain FEIS, DOE assumed that all surface construction activities and associated fugitive dust releases would occur during 250 working days per year with one 8-hour shift per day. The EPA-preferred method would be to break the construction activities into their component activities (for example, earth moving and truck traffic) and calculate the emissions for each component. However, information to that detail was not available for the construction period, so DOE took a generic, conservative approach similar to that in the Yucca Mountain FEIS. The estimated release rate of total suspended particulates (particulates with aerodynamic diameters of 30 micrometers or less) would be 0.27 kilogram per square meter (1.2 tons per acre) per month (DIRS 101824-EPA 1995, pp. 13.2.3-1 to 13.2.3-7). The Department based this estimated rate on measurements from the construction of apartment buildings and shopping centers.

Although the estimated release rate of total suspended particulates would be 0.27 kilogram per square meter (1.2 tons per acre) per month, the amount of PM_{10} emissions would be less than that amount. Many of the total suspended particulates from construction would be in the 10- to 30-micrometer range and would tend to settle rapidly (DIRS 102180-Seinfeld 1986, pp. 26 to 31). Experiments on dust suppression due to construction found that at 50 meters (160 feet) downwind of the source, a maximum of 30 percent of the remaining suspended particulates at respirable height were in the PM_{10} range (DIRS 103678-Midwest Research Institute 1988, pp. 22 to 26). Based on this factor, only 30 percent of the 0.27 kilogram per square meter per month of total suspended particulates, or 0.081 kilogram per square meter (0.36 ton per acre) per month, would be emitted as PM_{10} from construction activities. Because DOE based the default emission rate on continuous emissions over 30 days, the daily PM_{10} emission rate would be 0.0027 kilogram per square meter per day (0.012 ton per acre), or 0.00011 kilogram per square meter (0.00050 ton per acre) per hour. Although normal dust suppression activities would reduce PM_{10} emissions, the analysis took no credit for such activities.

The estimation of the annual and 24-hour average PM_{10} emission rates required an estimate of the size of the area DOE would disturb along with the unit area emission rate [0.00011 kilogram per square meter (0.00050 ton per acre) per hour] times 8 hours of construction per day. The analysis assumed that site preparation activities during the construction period would disturb the entire land area required for construction at the surface geologic repository operations area and vicinity and the South Portal development area, even though DOE would not build all facilities during that period. The analysis estimated that 20 percent of the total disturbed land area would be actively involved in construction activities at any given time; this was based on the total disturbed area at the end of the construction period divided by the 5 years that construction activities would last. Table B-5 lists the total area of disturbance at repository operations areas. Similarly, the analysis assumed that storage preparation activities would disturb the entire land area required for excavated rock storage (for both the construction and operations periods), although DOE would use only a portion of the area for storage during the construction period. Table B-6 lists fugitive dust emissions from surface construction; Table B-7 lists estimated air quality impacts from fugitive dust as a pollutant concentration and as a percent of the applicable regulatory limit. Because DOE based the calculation of the PM_{10} emissions solely on the area of disturbed land, the calculations are independent of the number, specific location, or type of structures the Department would construct on the disturbed land.

Fugitive dust from construction would produce small PM_{10} concentrations at the analyzed land withdrawal boundary. The maximum 24-hour average concentration of PM_{10} for construction in the land withdrawal area would be less than 20 percent of the regulatory limit. The maximum 24-hour average concentration of PM_{10} for construction outside the land withdrawal area could be approximately

Table B-5. Land area (square kilometers) disturbed during the construction period.

Operations area	Disturbed land
North and South Portal areas	
North Portal site	2.8
Topsoil storage location near North Portal site	0.061
North Portal site ancillary support facilities	0.14
North Portal site protective forces administrative facility	0.081
Aging pads	0.57
Subsurface intake/exhaust shafts (and access roads)	0.24
South Portal area	0.081
Muck storage (excavated rock pile)	0.81
Rail Equipment Maintenance Yard and associated rail facilities	0.4
Other—in land withdrawal area	
Main access road	2.3
Gate 510 security complex	0.11
Primary roads	0.4
Aggregate quarry/engineered fill quarry	0.4
Infrastructure: Power lines	0.12
Other—outside land withdrawal area	
Intersection at U.S. Highway 95	0.11
Disturbed land outside the land withdrawal area	0.26
Infrastructure: Offsite Sample Management Facility	0.012
Total land disturbance	8.8
Area disturbed per year	1.8

Source: DIRS 182827-Morton 2007, all.
Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures; therefore, totals might differ from sums.

40 percent of the regulatory limit at a receptor distance of 100 meters (330 feet) from the construction source.

B.5.2 FUGITIVE DUST EMISSIONS FROM SUBSURFACE EXCAVATION

The excavation of rock from the repository would release fugitive dust. Consistent with the methodology in the Yucca Mountain FEIS, this analysis assumed that subsurface excavation activities would take place 250 days per year in three 8-hour shifts per day. Excavation would generate dust in the tunnels, some of which would be emitted to the surface atmosphere through the ventilation system. DOE estimated the amount of dust the ventilation system would emit by using engineering judgment and best available information (DIRS 104494-CRWMS M&O 1998, p. 37). Table B-8 lists the release rates of PM_{10} for excavation activities. Table B-9 lists estimated air quality impacts from fugitive dust as a pollutant concentration in air and as a percentage of the regulatory limit.

Fugitive dust emissions from excavation would produce small offsite PM_{10} concentrations. The maximum 24-hour average concentration of PM_{10} would be less than 0.05 percent of the regulatory standard.

Dust from excavation would contain cristobalite, a form of crystalline silica that occurs naturally in Yucca Mountain tuffs. The analysis estimated the annual amounts of cristobalite releases by multiplying the amount of released dust (Table B-8) by the percentage of cristobalite in the parent rock (28 percent). Table B-9 lists potential air quality impacts for releases of cristobalite from excavation of the repository. Because there are no public exposure limits for cristobalite, DOE compared the annual average

Table B-6. Fugitive dust releases from surface construction (PM_{10}).

Period	Pollutant emission (kilograms)	Emission rate (grams per second)
North and South Portal areas		
Annual[a]	230,000	7.2
24-hour	910	31[b]
Other–in land withdrawal area		
Annual[a]	150,000	4.6
24-hour	580	20[b]
Other–outside land withdrawal area		
Annual[a]	17,000	0.54
24-hour	68	2.4[b]
Total		
Annual[a]	390,000	12
24-hour	1,600	54[b]

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures; therefore, totals might differ from sums.

a. NAAQS annual PM_{10} regulatory limit revoked December 17, 2006; therefore, DOE did not consider the annual PM_{10} impact further. The annual pollutant emission is listed here for comparison purposes only.

b. Based on an 8-hour release period.

NAAQS = National Ambient Air Quality Standards.

concentration to a derived benchmark level for the prevention of silicosis (Section B.1). The offsite cristobalite concentration would be less than 0.003 percent of this benchmark.

Table B-7. Estimated fugitive dust air quality impacts (micrograms per cubic meter) from surface construction (PM_{10}).

Operations area	Period	Maximum concentration[a]	Regulatory limit	Percent of limit[a]
North and South Portal areas (receptors at boundary of land withdrawal area)	24-hour	27	150	18
Other–in land withdrawal area (receptors at boundary of land withdrawal area)	24-hour	2.1	150	1.4
Other–outside land withdrawal area (receptors 100 meters from construction activity	24-hour	64	150	43

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Numbers are rounded to two significant figures.

Table B-8. Fugitive dust (PM_{10}) releases from excavation activities.

Period	Emission (kilograms)	Emission rate (grams per second)
Annual	920	0.029
24-hour	3.7	0.043[a]

Source: DIRS 155970-DOE 2002, Table G-7; amount of rock excavated by the Proposed Action is within the range evaluated by the Yucca Mountain FEIS.

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Based on a 24-hour release period.

Table B-9. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from excavation activities.

	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
PM_{10}	24-hour	0.067	150	0.045
Cristobalite	Annual	0.00022	10[b]	0.0022

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.
b. This value is a benchmark; there is no regulatory limit for exposure of cristobalite to the general public (Section B.1).

B.5.3 FUGITIVE DUST FROM EXCAVATED ROCK PILE

The storage of rock from the repository on the excavated rock pile would generate fugitive dust. The unloading of the rock and subsequent smoothing of the rock pile, as well as wind erosion, would release dust. Consistent with the methodology in the Yucca Mountain FEIS, DOE used the total suspended particulate emission for active storage piles to estimate fugitive dust emission. The equation is:

$$E = 1.9 \times (s \div 1.5) \times [(365 - p) \div 235] \times (f \div 15) \qquad \text{(Equation B-1)}$$

where

- E = total suspended particulate emission factor (kilogram per day per hectare [1 hectare = 0.01 square kilometer = 2.5 acres])
- s = silt content of aggregate (percent)
- p = number of days per year with 0.25 millimeter (0.0098 inch) or more of precipitation
- f = percentage of time wind speed exceeds 5.4 meters per second (12 miles per hour) at pile height.

This analysis assumed the same variables as those used in Section G.1.4.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-9 to G-11): s is equal to 4 percent, based on the average silt content of limestone quarrying material; p is 37.75 days; and f is 16.5 percent. Thus, E is equal to 780 kilograms of total particulates per day per square kilometer (6.9 pounds per day per acre). Using the assumption in the Yucca Mountain FEIS that only about 50 percent of the total particulates would be PM_{10} (DIRS 103676-Cowherd et al. 1988, pp. 4-17 to 4-37), the emission rate for PM_{10} would be 390 kilograms per day per square kilometer (3.5 pounds per day per acre).

The analysis used the size of the area that would be actively involved in storage and maintenance to estimate fugitive dust from disposal and storage. The unloading of excavated rock and the subsequent contouring of the pile would actively disturb only a portion of the excavated rock pile, and only that portion would be an active source of fugitive dust. The analysis assumed that either natural processes or DOE stabilization measures would stabilize the rest of the rock pile, which would release small amounts of dust. The application of dust suppression measures to the active area of the pile would reduce the calculated releases.

DOE used the calculations in Section G.1.4.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-9 and G-10) as the basis of its estimate of the size of the active portion of the excavated rock pile because the amount of excavated rock in the Proposed Action would be within the range of the FEIS analysis. DOE assumed the area of the rock pile would be between 0.26 and 0.28 square kilometer (0.1 to 0.11 square mile), the height of the pile would be between 6 and 8 meters (20 and 26 feet), and the average annual active area would be between 0.10 and 0.11 square kilometers (0.039 and 0.042 square mile). The analysis assumed the maximum release of PM_{10} during construction would be 44 kilograms (97 pounds) per 24-hour period. The emission rate would be 0.51 grams (0.018 ounces) per second.

Table B-10 lists estimated air quality impacts from fugitive dust as a pollutant concentration and as a percent of the applicable regulatory limit. The table also lists potential air quality impacts from releases of cristobalite. The analysis used the same methods as those in Section B.5.2, in which DOE assumes that cristobalite would be 28 percent of the fugitive dust released.

Table B-10. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from the excavated rock pile during the construction period.

	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
PM_{10}	24-hour	0.80	150	0.53
Cristobalite	Annual	0.0038	10[b]	0.038

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.
b. This value is a benchmark; there is no regulatory limit for exposure of cristobalite to the general public (Section B.1).

Fugitive dust emissions from the excavated rock pile would produce small offsite PM_{10} concentrations. The maximum 24-hour average concentration of PM_{10} would be approximately 0.5 percent of the regulatory standard. The offsite cristobalite concentration would be less than 0.04 percent of the benchmark.

B.5.4 FUGITIVE DUST FROM CONCRETE BATCH FACILITY

During the construction period three concrete batch plants would emit fugitive dust. Two plants would have a capacity of 190 cubic meters (250 cubic yards) per hour and one would have a capacity of 115 cubic meters (150 cubic yards) per hour. For this analysis and consistent with the methodology in Section G.1.4.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-11 to G-12), DOE assumed that the three plants would run 3 hours a day and 250 days per year. The three facilities would have a combined capacity of 495 cubic meters (650 cubic yards) of concrete per hour, 1,500 cubic meters (2,000 cubic yards) per day, and 370,000 cubic meters (480,000 cubic yards) per year. However, the Proposed Action would require an average of only 65,000 cubic meters (85,000 cubic yards) per year, or 260 cubic meters (340 cubic yards) per day during the construction period. Table B-11 lists emission factor estimates for a concrete batch facility (DIRS 182386-EPA 2006, pp. 11.12-4 and 11.12-5).

Table B-12 lists the particulate matter emission rates of the concrete batch facilities. The emission rate calculations assume that 1 cubic meter (1.3 cubic yards) of concrete weighs about 2,400 kilograms (5,300 pounds). The maximum concentration of PM_{10} for a 24-hour period during construction would be 6.6 micrograms per cubic meter at the boundary of the land withdrawal area, which is 4.4 percent of the regulatory limit.

B.5.5 FUGITIVE DUST FROM EXCAVATED ROCK REMOVAL

Excavated rock from construction of the Exploratory Studies Facilities is still at the North Portal. In preparation for construction of the repository, DOE would remove approximately 600,000 cubic meters (800,000 cubic yards) of fill and excavated rock, which the Department would either use during

Table B-11. Dust (PM_{10}) release rates for a concrete batch facility (kilograms per 1,000 kilograms of concrete).

Source/activity	Emission rate
Aggregate transfer	0.0017
Sand transfer	0.00051
Cement unloading to elevated storage silo	0.23
Weight hopper loading	0.0013
Mixer loading (central mix)	0.067

Source: DIRS 182386-EPA 2006, p. 11.12-4.
Notes: Conversion factors are on the inside back cover of this Repository SEIS. EPA updated emission rates in June 2006. Numbers are rounded to two significant figures.
EPA = U.S. Environmental Protection Agency.

Table B-12. Particulate matter (PM_{10}) release rates for concrete batch facilities during the construction period.

Period	Emission (kilograms)	Emission rate (grams per second)
Annual[a]	47,000	1.5
24-hour	190	17[b]

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.
a. NAAQS annual PM_{10} regulatory limit revoked December 17, 2006; therefore, DOE did not calculate annual PM_{10} impacts. The annual pollutant emission is shown here for comparison purposes only.
b. Based on a 3-hour release period.
DOE = U.S. Department of Energy.
NAAQS = National Ambient Air Quality Standards.

construction or move to an excavated rock pile in the South Portal development area (Chapter 2, Section 2.1.3).

DOE used the emission factor for aggregate handling and storage piles to estimate fugitive dust emission from movement of the excavated rock (DIRS 182386-EPA 2006, all). The equation is:

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \quad (\text{kilograms per metric ton}) \qquad \text{(Equation B-2)}$$

where

E = emission factor
k = particle size multiplier (dimensionless)
U = mean wind speed, meters per second
M = material moisture content (percent)
Kilograms per metric ton = 1,000 kilograms.

For this analysis, k is equal to 0.35 for PM_{10} (DIRS 177709-EPA 2006, p. 13.2.4-4), U is equal to 1.8 meters per second (DIRS 155970-DOE 2002, p. 3-15), and M is equal to 3.4 percent (DIRS 177709-EPA 2006, p. 13.2.4-2). Therefore the emission factor E is equal to 0.000205 kilograms of PM_{10} per kilogram of transferred material (0.41 pounds per ton).

Table B-13 lists fugitive dust emissions from the excavated rock pile removal. Table B-14 lists estimated air quality impacts from fugitive dust as the pollutant concentration in air and as the percent of the applicable regulatory limit.

Table B-13. Fugitive dust releases from excavated rock pile removal (PM_{10}).

Period	Cubic meters of rock moved	Kilograms of rock moved[a]	Pollutant emission (kilograms)	Emission rate (grams per second)
Annual[b]	600,000	910,000,000	190,000	5.9
24-hour[c]	2,400	3,700,000	750	26[d]

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Assume 1 cubic meter of packed earth weighs 1,522 kilograms.

b. NAAQS annual PM_{10} regulatory limit revoked December 17, 2006; therefore, DOE did not calculate annual PM_{10} impact. The annual pollutant emission is listed here for comparison purposes only.

c. Based on 250 working days per year.

d. Based on an 8-hour release period.

DOE = U.S. Department of Energy.

NAAQS = National Ambient Air Quality Standards.

Table B-14. Fugitive dust (PM_{10}) air quality impacts (micrograms per cubic meter) from excavated rock pile removal during the construction period.

	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
PM_{10}	24-hour	22	150	15
Cristobalite	Annual	0.044	10[b]	0.44

Note: Receptors at boundary of land withdrawal area.

a. Numbers are rounded to two significant figures.

b. This value is a benchmark; there is no regulatory limit for exposure of cristobalite to the general public (Section B.1).

B.5.6 EXHAUST EMISSIONS FROM CONSTRUCTION EQUIPMENT

Diesel- and gasoline-powered vehicles and equipment would emit the criteria pollutants carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (PM_{10} and $PM_{2.5}$) during the construction period. DOE estimated emissions from diesel equipment by applying standard EPA emission rates for nonroad diesel construction equipment to the amount of fuel the equipment would use (DIRS 174089-EPA 2004, all). Because legislation has mandated newer and cleaner diesel equipment after 2003, DOE estimated the emission factors from Tier 3 emissions standards (typically 2006 to 2010 model-year equipment). The emission factors assumed construction equipment with an engine size between 176 and 300 horsepower. The EPA emission rates are in grams per horsepower-hour, so DOE converted liters of diesel fuel to horsepower-hours.

Table B-15 lists the emission rates for an average piece of construction equipment. Table B-16 lists the estimated average amount of fuel that DOE would use per year during the construction period and the equivalent horsepower-hours. Table B-17 lists pollutant releases from construction equipment. Table B-18 lists the air quality impacts from construction equipment emission as the pollutant concentration in air and percent of the applicable regulatory limit.

Table B-15. Pollutant emission rates (grams per horsepower-hour) for construction equipment.

Pollutant	Estimated emission	
	Diesel[a]	Gasoline[b]
Carbon monoxide	0.7475	37.1
Nitrogen dioxide	2.5	4.
Sulfur dioxide	0.005	0.11
PM_{10}	0.15	0.16
$PM_{2.5}$	0.1455	0.16[c]
Hydrocarbons	0.1836	1.9

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Assume the horsepower rating for construction equipment is between 176 and 300 horsepower.

a. Source: DIRS 174089-EPA 2004, p. A6.

b. Source: DIRS 182387-EPA 1997, all; DIRS 103679-EPA 1991, pp. II-7-1 and II-7-7.

c. Assume PM_{10} is 100 percent $PM_{2.5}$.

Table B-16. Average amount of fuel use per year during the construction period and equivalent horsepower-hours.

Location consumed[a]	Diesel (liters)	Diesel (hp-hr)	Gasoline (liters)	Gasoline (hp-hr)
In LWA	3,500,000	19,000,000	150,000	830,000
Outside LWA	160,000	870,000	6,900	38,000
Total	3,600,000	20,000,000	160,000	870,000

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers rounded to two significant figures; therefore, totals might differ from sums.

a. DOE estimated the amount of fuel use in and outside the LWA by multiplying the percentage of disturbed land in or outside the area by the total amount of fuel use during the construction period.

hp-hr = horsepower-hour.

LWA = Land withdrawal area.

B.6 Operations and Monitoring Periods

This section describes the methods DOE used to estimate air quality impacts during the operations and monitoring periods. The operations period would begin upon receipt of a license to receive and possess radiological materials and would last up to 50 years. During the operations period, DOE would complete surface construction Phases 2, 3, and 4; continue subsurface development; and construct and operate the North Construction Portal. These activities would occur while the receipt, handling, aging, emplacement, and monitoring of waste were occurring.

The monitoring period would begin at the completion of the operations period and would continue for 50 years after the emplacement of the final waste package. Activities during the monitoring period would include maintenance of active ventilation for up to 50 years, remote inspections of waste packages, continuing investigations to support predictions of postclosure repository performance, and retrieval of waste packages to correct detected problems, if necessary. No construction activities would occur. Due to a major decline in activities during the monitoring period, the impacts to air quality would be much less than those during the construction or operations periods.

For this analysis and consistent with the methodology in Section G.1.5 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-16 to G-21), workers would use the following schedule for activities during the operations and monitoring periods: three 8-hour shifts a day, 5 days a week, 50 weeks a year.

Table B-17. Pollutant release rates from surface equipment during construction period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Construction in land withdrawal area			
Nitrogen dioxide	Annual	51,000	1.6
Sulfur dioxide	Annual	190	0.006
	24-hour	0.76	0.026
	3-hour	0.28	0.026
Carbon monoxide	8-hour	180	6.2
	1-hour	22	6.2
PM_{10}	24-hour	12	0.41
$PM_{2.5}$	Annual	2,900	0.092
	24-hour	12	0.40
Construction outside land withdrawal area			
Nitrogen dioxide	Annual	2,300	0.074
Sulfur dioxide	Annual	8.7	0.00028
	24-hour	0.035	0.0012
	3-hour	0.013	0.0012
Carbon monoxide	8-hour	8.3	0.29
	1-hour	1	0.29
PM_{10}	24-hour	0.55	0.019
$PM_{2.5}$	Annual	130	0.0042
	24-hour	0.53	0.018

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.
a. Based on an 8-hour release for averaging periods of 24 hours or less.

Maintenance of the excavated rock pile would occur in one 8-hour shift a day, 5 days a week, 50 weeks a year.

The analysis estimated air quality impacts by calculating pollution concentrations from operations and monitoring activities. It developed emission rates for each activity that would result in pollutant releases and multiplied the emission rates by the unit release concentrations (Section B.4) to calculate the pollutant concentrations for comparison to regulatory limits.

The principal sources of particulate matter would be dust emissions from surface construction (which would include an aging pad), concrete batch facility operations, excavation, and storage in the excavated rock pile. Surface construction would occur during the first 5 years of the operations period. Emissions from the North Portal boiler, standby generators, and emergency generators would be sources of nitrogen dioxide, sulfur dioxide, carbon monoxide, and $PM_{2.5}$. Fuel combustion from waste handling equipment, surface construction equipment, and equipment to maintain the excavated rock pile would be additional sources of these criteria pollutants. The following sections describe these sources in greater detail.

B.6.1 FUGITIVE DUST FROM SURFACE CONSTRUCTION

Construction of the remaining surface facilities, the North Construction Portal, and the remaining aging pad during the operations period would emit fugitive dust. For this analysis and consistent with the **Table**

B-18. Air quality impacts from construction equipment during the construction period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Construction in land withdrawal area (receptors at boundary of land withdrawal area)				
Nitrogen dioxide	Annual	0.043	100	0.043
Sulfur dioxide	Annual	0.00016	80	0.0002
	24-hour	0.023	365	0.0062
	3-hour	0.18	1,300	0.014
Carbon monoxide	8-hour	16	10,000	0.16
	1-hour	130	40,000	0.32
PM_{10}	24-hour	0.36	150	0.24
$PM_{2.5}$	Annual	0.0024	15	0.016
	24-hour	0.34	35	1.0
Construction outside land withdrawal area (receptors 100 meters from construction activity)				
Nitrogen dioxide	Annual	1	100	1.0
Sulfur dioxide	Annual	0.004	80	0.0051
	24-hour	0.032	365	0.0088
	3-hour	0.24	1,300	0.019
Carbon monoxide	8-hour	21	10,000	0.21
	1-hour	170	40,000	0.42
PM_{10}	24-hour	0.51	150	0.34
$PM_{2.5}$	Annual	0.057	15	0.38
	24-hour	0.49	35	1.4

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Numbers are rounded to two significant figures.

Table B-19. Land area (square kilometers) disturbed during the operations period.

Description	Total disturbed land	Percent disturbed during operations period	Land disturbed during operations period	Land disturbed per year during operations period[a]
North Portal site	2.8	50	1.4	0.28
Aging pads	0.57	75	0.43	0.085
Surface geologic repository operations area and vicinity	0.081	100	0.081	0.016
Totals[b]			1.9	0.38

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Assume that surface construction would occur during only the first 5 years of the operations period and that equal amounts of land would be disturbed during each of those 5 years.

b. Numbers are rounded to two significant figures; therefore, totals might differ from sums.

methodology in Section G.1.5 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. G-16), DOE assumed that some construction would disturb portions of land that had previously been disturbed during the construction period.

The analysis assumed the disturbance of an equal amount of land every year during the 5 years of surface construction in the operations period. Table B-19 lists the areas surface construction would disturb. The estimated annual amount of land disturbed during the operations period would be about 21 percent of that during the construction period.

The estimated PM_{10} emissions and emission rates during the operations period would be 21 percent of the total during the construction period (Section B.5.1, Table B-6) based on the amount of land disturbed. The PM_{10} concentration would be about 3.9 percent of the regulatory limit. Although normal dust suppression activities would reduce PM_{10} emissions, the analysis took no credit for such activities.

B.6.2 FUGITIVE DUST FROM CONCRETE BATCH FACILITY

For this analysis and consistent with the methodology in Section G.1.5.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-16 and G-17), DOE assumed that the concrete batch facilities it would use during construction would operate during the first 4 years of the operations period. The Proposed Action would require an average of 42,000 cubic meters (55,000 cubic yards) per year, or 170 cubic meters (220 cubic yards) per day during those 4 years. The dust release rate and potential air quality impacts for the operation period would be about 64 percent of those for the construction period (Section B.5.4). The PM_{10} concentration would be about 2.8 percent of the regulatory limit.

B.6.3 FUGITIVE DUST FROM SUBSURFACE EXCAVATION

This section summarizes and incorporates by reference Section G.1.5.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. G-17). The excavation of rock from the repository would generate fugitive dust in the drifts and some of the dust would reach the atmosphere through the repository ventilation system. The subsurface excavation activity during the operations period would be similar to the activity during the construction period; thus, fugitive dust emission rates from excavation during operations would be similar to those during the construction period. The fugitive dust release rate and potential air quality impacts for excavation of rock would be the same as those in Section B.5.2 for construction.

Tables B-8 and B-9 list the impacts of fugitive dust from subsurface excavation during construction. Air quality impacts from cristobalite releases during subsurface excavation would be the same as those in Table B-9. The PM_{10} concentration would be 0.045 percent of the regulatory limit and the cristobalite concentration would be 0.0022 percent of the benchmark.

B.6.4 FUGITIVE DUST FROM EXCAVATED ROCK PILE

The storage of rock on the excavated rock pile would release fugitive dust during the operations period. For this analysis and consistent with the methodology in Section G.1.5.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-17 to G-19), the fugitive dust emissions and release rate would depend on the active area of the excavated rock pile. While the land area DOE would use for storage of excavated rock during the operations period would be nearly twice as large as that used during the construction period, the active area per year would be approximately 50 percent as large due to the larger number of years over which continued development would occur. The annual emissions, emission rate, and maximum concentration of PM_{10} for the operations period would be 50 percent of that for the construction period (Section B.5.3). The PM_{10} concentration would be 0.26 percent of the regulatory limit, and the cristobalite concentration would be 0.018 percent of the regulatory limit.

B.6.5 EXHAUST EMISSIONS FROM SURFACE EQUIPMENT

Surface equipment would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter during surface operations, excavated rock pile maintenance, and surface facility construction. Consistent with the methodology in Section G.1.5.5 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-19 to G-20), the analysis used the same method to determine air quality impacts from surface equipment during operations as that for construction (Section B.5.6).

During the first 5 years of the operations period, while construction activities were occurring, the annual diesel fuel use would be 101 percent of that during the construction period. Annual gasoline use during those 5 years would be 488 percent of that during the construction period. The increase in gasoline use would be due to the use of trucks, cars, and four-wheel drive vehicles during operations activities.

After the 5 years of construction activities, the annual diesel fuel use would be 55 percent of that during construction. The decrease in diesel fuel use would be a direct result of the completion of surface construction and the associated decrease in the use of construction equipment. Annual gasoline use would be 539 percent of that during the construction period. Gasoline use would not decrease in comparison to the construction period because few construction vehicles would use gasoline and the number of gasoline-powered vehicles for operations would increase after the 5 years of construction.

Table B-20 lists the pollution release rates during the first 5 years of the operations period, when the total amount of release would be greatest. Table B-21 lists the air quality impacts from surface equipment emissions.

Table B-20. Pollutant release rates from surface equipment during the first 5 years of the operations period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	67,000	2.1
Sulfur dioxide	Annual	580	0.019
	24-hour	2.3	0.081
	3-hour	0.88	0.081
Carbon monoxide	8-hour	690	24
	1-hour	86	24
PM_{10}	24-hour	15	0.51
$PM_{2.5}$	Annual	3,600	0.11
	24-hour	14	0.50

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Based on an 8-hour release for averaging periods of 24 hours or less.

Because volatile organic compounds are a precursor for ozone production, DOE's analysis of ozone evaluated the quantity of volatile organic compounds emitted annually during the operations period. Approximately 12,000 kilograms (26,000 pounds) of hydrocarbons would be released annually by surface equipment during operations.

B.6.6 EXHAUST EMISSIONS FROM BOILERS AND GENERATORS

Diesel plant heating boilers in the North Portal operations area would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter. The basis for the emission calculations would be fuel

Table B-21. Air quality impacts from surface equipment during the first 5 years of the operations period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.056	100	0.056
Sulfur dioxide	Annual	0.00049	80	0.00061
	24-hour	0.07	365	0.019
	3-hour	0.56	1,300	0.043
Carbon monoxide	8-hour	61	10,000	0.62
	1-hour	490	40,000	1.2
PM_{10}	24-hour	0.44	150	0.29
$PM_{2.5}$	Annual	0.003	15	0.02
	24-hour	0.43	35	1.2

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.

consumption during the 5-year period of increasing operations activities when the annual total emissions would be greatest for the operations period due to emissions from construction equipment. The boilers would be industrial water tube boilers. Table B-22 lists the emission factors for a commercial/industrial diesel boiler with a size of 10 to 100 million British thermal units per hour (EPA type SCC 1-03-005-02). The diesel boilers would consume an average of 13 million liters (3.4 million gallons) per year during the initial 5-year period and about 17 million liters (4.5 million gallons) per year at full operations. Table B-23 lists pollutant releases by diesel boilers during the operations period. Table B-24 lists the air quality impacts from boiler emissions. Approximately 860 kilograms (1,900 pounds) of total organic carbon would also be released annually by boilers and would add to the amount of volatile organic compounds released during operations.

Table B-22. Pollutant emission rates for commercial/industrial diesel boiler.

	Estimated emission	
Pollutant	Pounds per 1,000 gallons diesel burned[a]	Kilograms per 1,000 liters diesel burned[b]
Carbon monoxide	5	0.6
Nitrogen dioxide (uncontrolled)	20	2.4
Sulfur dioxide	0.21[c]	0.026
PM_{10}	2.4	0.29
$PM_{2.5}$	2.1	0.26

Source: EPA Factor Information Retrieval (FIRE) software version 6.25.
a. Actual emission factor from EPA FIRE 6.25.
b. Calculated emission factor.
c. Assumes 0.0015 percent sulfur in fuel (15 parts per million).

The air quality impacts from the boilers during full repository operations would be 130 percent of the results in Tables B-23 and B-24; the boilers' fuel consumption would be 130 percent greater during full operations than during the initial 5-year period. Even though impacts from boilers would be greater during full repository operations, the annual total emissions from all sources would be greater during the 5-year period of increasing operations because of the large quantity of fuel burned by construction vehicles during that period. The impact from boiler emissions was thus combined with impacts from the 5-year period of surface construction in order to calculate the most conservative combined impact.

Table B-23. Pollutant release rates from diesel boilers during first 5 years of operations period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	31,000	1
Sulfur dioxide	Annual	330	0.01
	24-hour	1.3	0.046
	3-hour	0.49	0.046
Carbon monoxide	8-hour	31	1.1
	1-hour	3.9	1.1
PM_{10}	24-hour	15	0.51
$PM_{2.5}$	Annual	3,300	0.1
	24-hour	13	0.46

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.
a. Based on an 8-hour release for averaging periods of 24 hours or less.

Table B-24. Air quality impacts from diesel boilers during the first 5 years of the operations period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.026	100	0.026
Sulfur dioxide	Annual	0.00028	80	0.00035
	24-hour	0.039	365	0.011
	3-hour	0.31	1,300	0.024
Carbon monoxide	8-hour	2.8	10,000	0.028
	1-hour	22	40,000	0.055
PM_{10}	24-hour	0.44	150	0.29
$PM_{2.5}$	Annual	0.0028	15	0.018
	24-hour	0.39	35	1.1

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.

The emergency and standby diesel generators would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter. The analysis assumed that the generators would be 4,500 kilowatts. The basis for the emission calculations would be annual fuel consumption during the operations period. It is assumed that annual diesel fuel usage for the generators would be constant through the operations period and would not be affected by the increasing repository operations during the first 5 years of the period.

Table B-25 lists the emission factors for a large stationary diesel engine (EPA type SCC 2-02-004-01). Table B-26 lists the amount of fuel consumed per year by the diesel generators.

Table B-27 lists pollutant releases by diesel generators during the operations period. Approximately 850 kilograms (1,900 pounds) of volatile organic compounds would also be released annually by the generators.

Table B-28 lists the air quality impacts from diesel generator emissions.

Table B-25. Pollutant emission rates for large stationary diesel engine.

Pollutant	Estimated emissions: Pounds per 1,000 gallons diesel burned[a]	Estimated emissions: Kilograms per 1,000 liters diesel burned[b]
Carbon monoxide	116	14
Nitrogen dioxide (uncontrolled)	438	52
Sulfur dioxide	0.207[c]	0.025
PM_{10}	7.85	0.94
$PM_{2.5}$	7.55	0.90

Source: EPA FIRE software version 6.25.
a. Actual emission factor from EPA FIRE 6.25.
b. Calculated emission factor.
c. Assumes 0.0015 percent sulfur in fuel (15 parts per million).

Table B-26. Amount of fuel consumed per year by diesel generators.

Generator type	Fuel use per year (liters)
Emergency diesel generator	160,000
Standby diesel generator	670,000
Total	830,000

Table B-27. Pollutant release rates from diesel generators during the operations period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	44,000	1.4
Sulfur dioxide	Annual	21	0.00066
	24-hour	0.083	0.0029
	3-hour	0.031	0.0029
Carbon monoxide	8-hour	46	1.6
	1-hour	5.8	1.6
PM_{10}	24-hour	3.1	0.11
$PM_{2.5}$	Annual	760	0.024
	24-hour	3.0	0.10

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.
a. Based on an 8-hour release for averaging periods of 24 hours or less.

B.7 Closure Period

This section describes the methods DOE used to estimate air quality impacts during the closure period at the proposed repository. The closure period would last 10 years and would overlap the last 10 years of the monitoring period. Activities during the closure period would include decontamination of the surface handling facilities, backfilling, sealing of subsurface-to-surface openings, construction of monuments to \mark the site, decommissioning and demolition of surface facilities, and restoration of the surface to its approximate condition before repository construction.

Table B-28. Air quality impacts from diesel generators during the operations period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.037	100	0.037
Sulfur dioxide	Annual	0.000018	80	0.000022
	24-hour	0.0025	365	0.00068
	3-hour	0.020	1,300	0.0015
Carbon monoxide	8-hour	4.2	10,000	0.042
	1-hour	33	40,000	0.083
PM_{10}	24-hour	0.094	150	0.062
$PM_{2.5}$	Annual	0.00063	15	0.0042
	24-hour	0.090	35	0.26

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.

For this analysis and consistent with the methodology in Section G.1.6 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-21 to G-25), DOE estimated air quality impacts by calculating pollutant concentrations from closure activities. The analysis developed emission rates for each activity that would result in release of pollutants and then multiplied the rates by the unit release concentration (Section B.4) to calculate the pollutant concentration for comparison to the regulatory limits.

The sources of particulate matter would be emissions from the backfill plant (discussed below in Section B.7.1) and concrete batch facility, fugitive dust from closure activities on the surface, and fugitive dust from the reclamation of material from the excavated rock pile for backfill. The principal source of nitrogen dioxide, sulfur dioxide, and carbon monoxide during closure would be fuel combustion. The following sections describe these sources in more detail.

B.7.1 DUST FROM BACKFILL ACTIVITIES

This section summarizes, incorporates by reference, and updates Section G.1.6.1 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. G-21). DOE assumed that much of the backfill would be processed rock from the excavated rock pile. The rock would be separated, crushed, screened, and washed in order to enhance the characteristics useful for closure backfill. As much as 91 metric tons (100 tons) an hour would be processed in a facility that would run 6 hours a shift, 2 shifts per day, 5 days a week, 50 weeks a year during the closure period. DOE assumed that the PM_{10} release amount would be 12,000 kilograms (26,000 pounds) per year, or 49 kilograms (110 pounds) per 24-hour period. The 24-hour emission rate would be 1.1 grams (0.039 ounces) per second, based on a 12-hour release period. The maximum concentration of PM_{10} would be 1.2 micrograms per cubic meter, which is 0.82 percent of the regulatory limit.

B.7.2 FUGITIVE DUST FROM CONCRETE BATCH FACILITY

This section summarizes, incorporates by reference, and updates Section G.1.6.2 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-22 and G-23). DOE assumed that the concrete batch facility to be used during the closure period would be similar to those used during the construction and operations periods (Sections B.5.4 and B.6.2, respectively). The primary difference would be that the plant would run only 10 3-hour shifts a year for each concrete seal. The analysis assumed that the plant would produce two seals per year. Consistent with Table G-33 in the Yucca Mountain FEIS, DOE assumed the PM_{10} release amount would be 120 kilograms (265 pounds) per 24-hour period, with an emission rate of 11 grams (0.39 ounce) per second over a 3-hour release period. The maximum concentration of PM_{10} would be 4.2 micrograms per cubic meter, which is 2.8 percent of the regulatory limit. The fugitive dust from concrete batch facilities would be less then that during the construction period.

B.7.3 FUGITIVE DUST FROM CLOSURE ACTIVITIES

This section summarizes, incorporates by reference, and updates Section G.1.6.3 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. G-23). DOE assumed that closure activities such as smoothing and reshaping of the excavated rock pile and demolition of buildings would produce virtually the same fugitive dust releases as construction activities because they would disturb nearly the same amount of land. However, because the activities would occur over a 10-year period rather than a 5-year period, the annual emissions would be lower. Sources of dust from surface demolition and decommissioning activities would include the North Portal area and roads, South Portal area and roads, ventilation shaft areas and access roads, the excavated rock pile, concrete batch plant, and aging pads. The analysis assumed that closure would not affect sites outside the land withdrawal area such as an intersection near U.S. Highway 95 and an offsite Sample Management Facility. Table B-29 lists PM_{10} release rates. The maximum concentration of PM_{10} would be 22 micrograms per cubic meter, which is 15 percent of the regulatory limit.

Table B-29. Fugitive dust releases from surface demolition and decommissioning (PM_{10}).

Period	Pollutant emission (kilograms)	Emission rate (grams per second)
Annual[a]	190,000	5.9
24-hour	740	26[b]

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures. Assumes 10 years for closure.

a. National Ambient Air Quality Standard annual PM_{10} regulatory limit revoked December 17, 2006; therefore, DOE did not consider annual PM_{10} impact further. The annual pollutant emission is listed for comparison purposes only.

b. Based on an 8-hour release period.

DOE = U.S. Department of Energy.

B.7.4 FUGITIVE DUST FROM EXCAVATED ROCK PILE

This section summarizes, incorporates by reference, and updates Section G.1.6.4 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. G-24 to G-25). DOE assumed that fugitive dust would occur from the removal of excavated rock from the rock pile during backfill operations. The amount of excavated rock in the Proposed Action is within the range evaluated by the FEIS. Consistent with Table G-37 in the FEIS, DOE assumed the PM_{10} release amount would be 30 kilograms (66 pounds) per 24-hour period, with an emission rate of 0.35 gram (0.012 ounce) per second, based on continuous release. Table B-30 lists PM_{10} air quality impacts from the excavated rock pile.

Table B-30 also lists potential air quality impacts for releases of cristobalite. The analysis used the same methods as those in Section B.5.2 for the construction period, in which DOE assumed cristobalite would be 28 percent of the fugitive dust releases, based on its percentage in the parent rock.

Table B-30. Fugitive dust (PM_{10}) and cristobalite air quality impacts (micrograms per cubic meter) from the excavated rock pile during the closure period.

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
PM_{10}	24-hour	0.55	150	0.37
Cristobalite	Annual	0.0026	10[b]	0.026

Note: Receptors at boundary of land withdrawal area.

a. Numbers are rounded to two significant figures.

b. This value is a benchmark; there is no regulatory limit for exposure of cristobalite to the general public (Section B.1).

B.7.5 EXHAUST EMISSIONS FROM SURFACE EQUIPMENT

This section summarizes, incorporates by reference, and updates Section G.1.6.5 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. G-25). The consumption of diesel fuel by surface equipment and backfilling equipment would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (PM_{10} and $PM_{2.5}$) during the closure period. DOE assumed the annual amount of diesel fuel use during closure would be 2 million liters (530,000 gallons). Table B-31 lists pollutant releases from diesel fuel use for the combination of surface equipment and backfilling equipment. Table B-32 lists air quality impacts. Exhaust emissions would be substantially less than those during the construction period.

Table B-31. Pollutant release rates from surface and backfilling equipment during the closure period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)[a]	Emission rate[b] (grams per second)
Nitrogen dioxide	Annual	27,000	0.87
Sulfur dioxide	Annual	55	0.0017
	24-hour	0.22	0.0076
	3-hour	0.082	0.0076
Carbon monoxide	8-hour	33	1.1
	1-hour	4.1	1.1
PM_{10}	24-hour	6.6	0.23
$PM_{2.5}$	Annual	1,600	0.051
	24-hour	6.4	0.22

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Mass of pollutant was calculated by using diesel emission factors from Table B-15.

b. Based on an 8-hour release for averaging periods of 24 hours or less.

Table B-32. Air quality impacts from diesel equipment during the closure period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.023	100	0.023
Sulfur dioxide	Annual	0.000045	80	0.000056
	24-hour	0.0065	365	0.0018
	3-hour	0.052	1,300	0.0040
Carbon monoxide	8-hour	2.9	10,000	0.029
	1-hour	24	40,000	0.059
PM_{10}	24-hour	0.20	150	0.13
$PM_{2.5}$	Annual	0.0013	15	0.0090
	24-hour	0.19	35	0.55

Note: Receptors at boundary of land withdrawal area.

a. Numbers are rounded to two significant figures.

B.7.6 RAIL CONSTRUCTION: FUGITIVE DUST EMISSIONS DURING CONSTRUCTION PERIOD

Activities associated with constructing the rail line would generate fugitive dust. Crystalline silica might be present in the rock DOE could use as ballast, and thus crystalline silica might be present in fugitive dust. For this analysis, and consistent with the Rail Alignment EIS, DOE assumed that all rail construction activities and associated fugitive dust releases would occur during a 12-hour work day with 250 working days per year. The estimated PM_{10} releases within the land withdrawal area from track construction would be about 150,000 kilograms (330,000 pounds) per year, or 610 kilograms (1,300 pounds) per day. The daily emission rate would be about 14 grams (0.49 ounce) per second. The maximum concentration of PM_{10} at the boundary of the land withdrawal area would be about 54 micrograms per cubic meter, which would be about 36 percent of the regulatory limit. Consistent with the methodology in the Rail Alignment EIS, these estimates assumed a 74-percent best management practice reduction of fugitive dust emissions. The highest maximum concentration of PM_{10} would be located at the receptor along the west boundary of the land withdrawal area. This receptor would be less than 500 meters (1,600 feet) from the location of the rail line.

B.7.7 RAIL CONSTRUCTION: EXHAUST EMISSIONS DURING CONSTRUCTION PERIOD

Diesel-powered vehicles and equipment would emit the criteria pollutants carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (both PM_{10} and $PM_{2.5}$) during the construction of the rail line in the land withdrawal area. DOE based its calculation of emissions on the types of equipment it would use during construction, the number of operating hours for the equipment, and the hourly emission factors. The Department used Tier 1 emission standards to obtain conservative estimates of emissions for rail activities. The highest maximum concentration of all criteria pollutants would be located at the receptor along the west boundary of the land withdrawal area. This receptor would be less than 500 meters (1,600 feet) from the location of the rail line. Table B-33 lists estimated pollutant releases from construction equipment. Table B-34 lists estimated air quality impacts from construction equipment emissions as the pollutant concentration in air and percent of the applicable regulatory limit.

B.7.8 RAIL FACILITY CONSTRUCTION: EXHAUST EMISSIONS DURING CONSTRUCTION PERIOD

Diesel-powered vehicles and equipment would emit the criteria pollutants carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (both PM_{10} and $PM_{2.5}$) during the construction of the Rail Equipment Maintenance Yard and associated facilities in the land withdrawal area. DOE based its calculation of emissions on the types of equipment it would use during construction, the number of operating hours for the equipment, and the hourly emission factors. The Department used Tier 1 emission standards to obtain conservative estimates of emissions for rail activities. Table B-35 lists estimated pollutant releases from construction equipment. Table B-36 lists estimated air quality impacts from construction equipment emissions as the pollutant concentration in air and percent of the applicable regulatory limit.

Table B-33. Rail construction pollutant release rates in the land withdrawal area from surface equipment during the construction period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	590,000	19
Sulfur dioxide	Annual	420	0.013
	24-hour	1.7	0.038
	3-hour	0.62	0.038
Carbon monoxide	8-hour	1,800	42
	1-hour	230	42
PM_{10}	24-hour	140	3.2
$PM_{2.5}$	Annual	34,000	1.1
	24-hour	140	3.1

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Based on a 12-hour release for averaging periods of 24 hours or less.

Table B-34. Rail construction air quality impacts from construction equipment in the land withdrawal area during the construction period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	2.7	100	2.7
Sulfur dioxide	Annual	0.0019	80	0.0024
	24-hour	0.15	365	0.040
	3-hour	0.61	1,300	0.047
Carbon monoxide	8-hour	250	10,000	2.5
	1-hour	2,000	40,000	5.1
PM_{10}	24-hour	12	150	8.2
$PM_{2.5}$	Annual	0.16	15	1.0
	24-hour	12	35	34

Note: Receptors at boundary of land withdrawal area.

a. Numbers are rounded to two significant figures.

Table B-35. Rail Equipment Maintenance Yard pollutant release rates from surface equipment during the construction period.

Pollutant	Period	Mass of pollutant per averaging period (kilograms)	Emission rate[a] (grams per second)
Nitrogen dioxide	Annual	84,000	2.7
Sulfur dioxide	Annual	71	0.0022
	24-hour	0.28	0.0098
	3-hour	0.11	0.0098
Carbon monoxide	8-hour	300	11
	1-hour	38	11
PM_{10}	24-hour	23	0.81
$PM_{2.5}$	Annual	5,700	0.18
	24-hour	23	0.79

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.
a. Based on an 8-hour release for averaging periods of 24 hours or less.

Table B-36. Rail Equipment Maintenance Yard air quality impacts from construction equipment during the construction period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.071	100	0.071
Sulfur dioxide	Annual	0.000058	80	0.000073
	24-hour	0.0084	365	0.0023
	3-hour	0.067	1,300	0.0052
Carbon monoxide	8-hour	27	10,000	0.27
	1-hour	220	40,000	0.54
PM_{10}	24-hour	0.7	150	0.47
$PM_{2.5}$	Annual	0.0048	15	0.032
	24-hour	0.68	35	1.9

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.

B.7.9 RAIL FACILITY EMISSIONS DURING OPERATIONS PERIOD

Air emissions from rail facilities in the analyzed land withdrawal area would occur during the operations period. They would include emissions from the Rail Equipment Maintenance Yard operations, vehicles, switch train locomotives, and fuel storage tanks. Table B-37 lists annual pollutant releases from these activities. Table B-38 lists air quality impacts from rail facilities and activities.

Table B-37. Annual pollutant emissions (kilograms) from rail facilities and activities during the operations period.

Pollutant	Rail Equipment Maintenance Yard	Rail Equipment Maintenance Yard trucks	Rail Equipment Maintenance Yard switch train locomotives	Fuel oil storage	Total rail facility emissions
Nitrogen dioxide	34,000	170	360,000	0	400,000
Sulfur dioxide	800	1	300	0	1,100
Carbon monoxide	10,000	190	150,000	0	160,000
PM_{10}	1,100	9.6	11,000	0	12,000
$PM_{2.5}$	1,000	8.9	9,600	0	11,000
Hydrocarbons	4,100	89	37,000	150	42,000

Source: Rail Alignment EIS.
Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures; therefore, totals might differ from sums.

Table B-38. Air quality impacts from rail facilities and activities during the operations period (micrograms per cubic meter).

Pollutant	Period	Maximum concentration[a]	Regulatory limit	Percent of regulatory limit[a]
Nitrogen dioxide	Annual	0.33	100	0.33
Sulfur dioxide	Annual	0.00093	80	0.0012
	24-hour	0.13	365	0.036
	3-hour	1.1	1,300	0.081
Carbon monoxide	8-hour	57	10,000	0.57
	1-hour	460	40,000	1.1
PM_{10}	24-hour	1.4	150	0.94
$PM_{2.5}$	Annual	0.009	15	0.06
	24-hour	1.3	35	3.6

Note: Receptors at boundary of land withdrawal area.
a. Numbers are rounded to two significant figures.

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Appendix C

Floodplain/Wetlands Assessment for the Proposed Yucca Mountain Geologic Repository

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C. FLOODPLAIN/WETLANDS ASSESSMENT FOR THE PROPOSED YUCCA MOUNTAIN GEOLOGIC REPOSITORY

This appendix presents the floodplain and wetlands assessment for the Proposed Action to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste. Section C.1 describes the regulatory basis and history for the assessment. Section C.2 describes the Proposed Action in terms of activities that could affect floodplains and wetlands, and Section C.3 characterizes the relevant existing environment. Section C.4 describes potential effects on floodplains (see Section C.1.2 for a discussion of effects on wetlands). Sections C.5 and C.6 discuss mitigation measures DOE would use and alternatives to the Proposed Action, respectively. Section C.7 contains the findings of the floodplains and wetlands assessment.

C.1 Introduction

Pursuant to Executive Order 11988, *Floodplain Management*, each federal agency, when it conducts activities in a floodplain, is to take actions to reduce the risk of flood damage; minimize the impacts of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. Pursuant to Executive Order 11990, *Protection of Wetlands*, each federal agency is to avoid, to the extent practicable, the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands if a practicable alternative exists. The U.S. Department of Energy (DOE or the Department) issued regulations that implement these Executive Orders (10 CFR Part 1022, *Compliance with Floodplain/Wetlands Environmental Review Requirements*). In accordance with the terms of these regulations, specifically 10 CFR 1022.11(d), DOE must prepare a floodplain assessment for proposed actions that would take place in floodplains and a wetlands assessment for proposed actions that would take place in wetlands. This appendix addresses DOE's obligations to perform a floodplain and wetlands assessment under 10 CFR Part 1022. The remainder of this section addresses pertinent past actions and decisions that could affect this assessment.

In 1982, Congress enacted the *Nuclear Waste Policy Act*, as amended (NWPA; 42 U.S.C. 10101 et seq.) in recognition of the national problem created by the accumulation of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites throughout the country. The Act recognized the Federal Government's responsibility to permanently dispose of the nation's spent nuclear fuel and high-level radioactive waste. In 1987, Congress amended the Act by redirecting DOE to determine the suitability of only Yucca Mountain in southern Nevada.

In 1989, DOE published a Notice of Floodplain/Wetlands Involvement (54 FR 63187; February 9, 1989) for site characterization studies at Yucca Mountain. The purpose of these studies was to determine the suitability of Yucca Mountain to isolate nuclear waste. DOE prepared a floodplain assessment (DIRS 104559-YMP 1991, all) and issued a Statement of Findings (56 FR 49765; October 1, 1991). In 1992, DOE prepared a second floodplain assessment on the cumulative impacts of surface-based investigations and the location of part of the Exploratory Studies Facility in the 100-year floodplain of a wash at Yucca Mountain (DIRS 103197-YMP 1992, all) and published the Statement of Findings (57 FR 48363; October 23, 1992). Both Statements of Findings concluded that the benefits of locating activities and structures in floodplains outweighed potential adverse impacts to the floodplains and that alternatives to these actions were not reasonable.

The NWPA requires that a final environmental impact statement (EIS) accompany a recommendation by the Secretary of Energy to the President to construct a repository. As part of the EIS process, and following the requirements of 10 CFR Part 1022, DOE issued a *Notice of Floodplain and Wetlands Involvement* (64 FR 31554; June 11, 1999). The Notice requested comments from the public on potential impacts on floodplains and wetlands from the construction of a rail line or an intermodal transfer station with its associated route for heavy-haul trucks to and in the vicinity of Yucca Mountain, depending on the rail or intermodal alternative DOE selected. DOE received no comments from the public.

In February 2002, DOE completed the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS). Appendix L of the Yucca Mountain FEIS contained a floodplain and wetlands assessment prepared in accordance with 10 CFR Part 1022. The assessment examined the potential effects of repository construction and operation and construction of either a rail line or an intermodal transfer station and its associated heavy-haul truck route on (1) floodplains near the Yucca Mountain site and (2) floodplains and areas that might have wetlands along the five rail corridors and the five heavy-haul truck routes. In the assessment Statement of Findings, DOE concluded that the proposed actions at Yucca Mountain would be unlikely to increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural beneficial values of the floodplains because there are no human activities or facilities upstream or downstream that such activities could affect. In addition, DOE committed to a more detailed floodplains evaluation and wetlands delineation along the selected route for transport of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. The Yucca Mountain FEIS identified rail as DOE's preferred mode of transportation, but did not identify a preference among the five rail corridors in Nevada.

By July 9, 2002, the recommendation to make Yucca Mountain the site for development of a geologic repository for spent nuclear fuel and high-level radioactive waste had passed from the Secretary of Energy to the President, then to Congress, and both the House of Representatives and the Senate had passed a joint resolution to approve the site. On July 23, 2002, the President signed Public Law 107-200, the *Yucca Mountain Development Act*, which paved the way for DOE to seek licenses from the U.S. Nuclear Regulatory Commission (NRC) to build and operate a repository at Yucca Mountain.

In a December 29, 2003, "Notice of Preferred Nevada Rail Corridor" (68 FR 74951), DOE named the Caliente rail corridor as its preferred route for construction of a rail line in Nevada. DOE published the corresponding Record of Decision (69 FR 18557) on April 8, 2004, and on the same date published a "Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV" (69 FR 18565). On October 13, 2006, the Department amended the scope of the Rail Alignment EIS to include the Mina rail corridor in addition to the Caliente rail corridor (71 FR 60484). On the same day, the Department published a "Notice of Intent to Prepare a Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV" (71 FR 60490). The purpose of the this *Draft Supplemental Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) is to address changes in the design and operation of the repository since the completion of the Yucca Mountain FEIS. This supplemental EIS will assist the NRC in the adoption, to the extent practicable, of any EIS prepared pursuant to Section 114(f)(4) of the NWPA.

This floodplain/wetlands assessment updates the floodplain and wetlands assessment that DOE included with the Yucca Mountain FEIS by addressing changes to the repository design and operational plans since 2002. Specifically, this assessment addresses potential effects of two elements: (1) the current repository facility layout and design, and (2) a group of infrastructure improvements that DOE recently proposed to do in the near-term, before starting repository construction actions. This latter element consists of several different actions at and near Yucca Mountain that DOE feels are necessary to continue ongoing activities and tests in a manner that ensures the health and safety of workers and visitors. DOE documented the proposed infrastructure improvements in the *Draft Environmental Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada* (DIRS 178817-DOE 2006, all), which it made available for public review on July 6, 2006 (Notice of Availability, 71 FR 38391). Appendix A of the Draft Environmental Assessment was a *Floodplain and Wetlands Assessment for the Proposed Infrastructure Improvements for the Yucca Mountain Project, Nevada*, which DOE has incorporated into this assessment.

The Nevada Rail Corridor SEIS and Rail Alignment EIS include an appendix containing a separate floodplain and wetlands assessment that provides a detailed floodplains evaluation and wetlands delineation along the Caliente and Mina rail corridors. As a result, this Repository SEIS (in contrast to the corresponding assessment in the Yucca Mountain FEIS) does not address potential impacts to floodplains and wetlands along the transportation corridors. There is, however, some overlap in the floodplains addressed in this document and those assessed in the Rail Alignment EIS because the rail line would cross some of the same drainage features at and near Yucca Mountain that repository construction would affect.

C.1.1 FLOODPLAIN DATA REVIEW

This assessment examines the potential effects of repository construction and operations on floodplains at and near the Yucca Mountain site. The floodplains of concern are those associated with Fortymile Wash, Busted Butte Wash (also known as Dune Wash), Drill Hole Wash, and Midway Valley Wash (also known as Sever Wash) (Figure C-1). These usually dry washes can fill with flowing water after very heavy, sustained rain or snow.

Title 10 CFR 1022.4 defines a flood or flooding as ". . . a temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters, or the unusual and rapid accumulation of runoff of surface waters from any source." It identifies floodplains that must be considered in the floodplain assessment as the base floodplain and the critical-action floodplain. The base floodplain is the area inundated by a flood having a 1-percent chance of occurrence in any given year (a 100-year floodplain). The critical-action floodplain is the area inundated by a flood having a 0.2-percent chance of occurrence in any given year (a 500-year floodplain). Critical action is any activity for which even a slight chance of flooding would be too great. Such actions could include the storage of highly volatile, toxic, or water-reactive materials. DOE considered the critical-action floodplain because it could use petroleum-based fuel, oil, lubricants, and other hazardous materials during the construction of repository facilities, including upgrades of roads, and because it could transport spent nuclear and high-level radioactive waste across washes and manage them at facilities adjacent to washes.

Title 10 CFR 1022.11 requires DOE to use Flood Insurance Rate Maps or Flood Hazard Boundary Maps to determine if a proposed action would be in the base or critical-action floodplain. On federal or state lands for which Flood Insurance Rate Maps or Flood Hazard Boundary Maps are not available, the

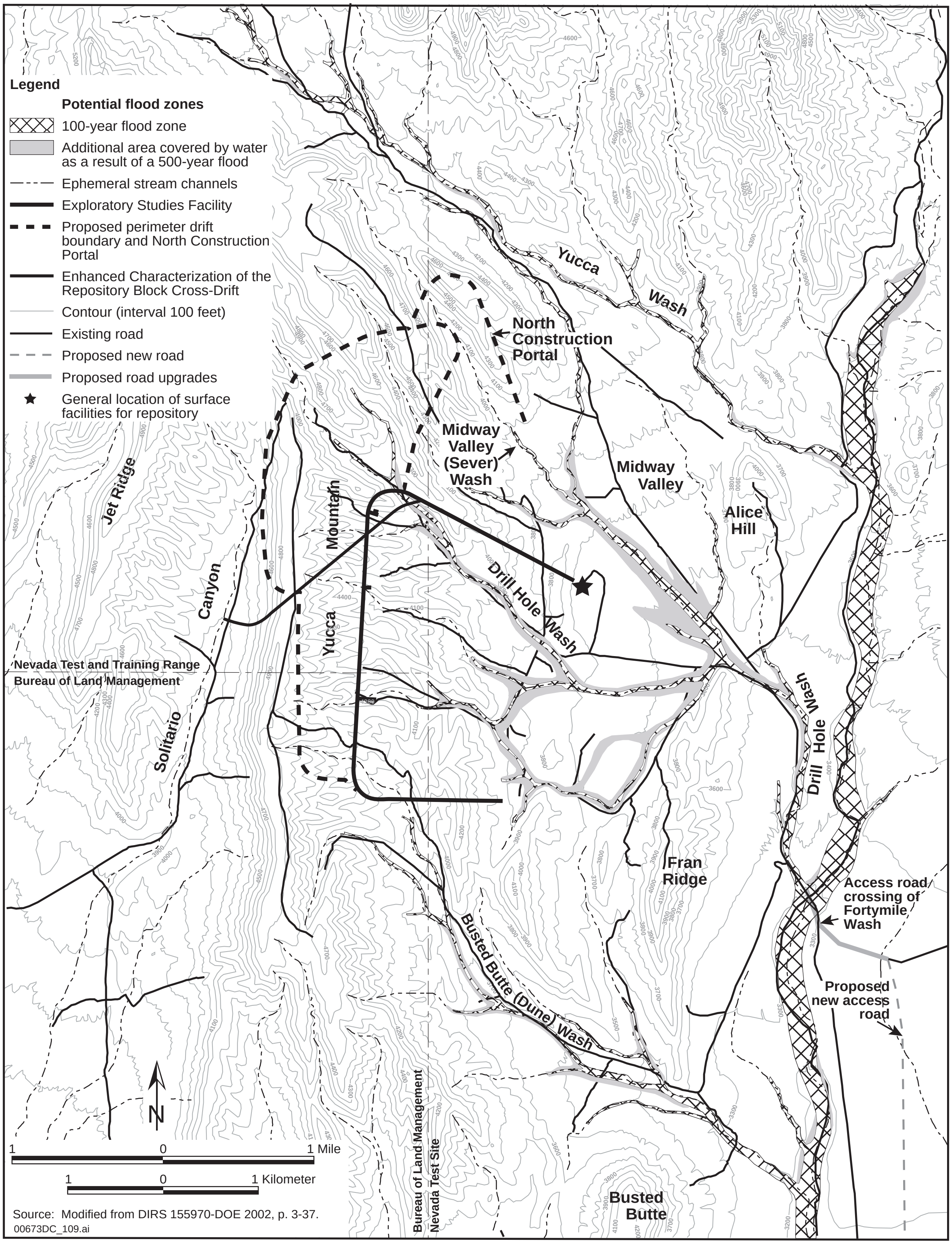

Figure C-1. Yucca Mountain site topography, drainage channels, and floodplains.

Department must seek flood information from the appropriate land management agency or from agencies with expertise in floodplain analysis. Therefore, DOE asked the U.S. Geological Survey to complete a flood study of Fortymile Wash and its principal tributaries (which include Busted Butte, Drill Hole, and Midway Valley washes) and outline areas of inundation from 100- and 500-year floods (DIRS 102783-Squires and Young 1984, Plate 1). Figure C-1 shows the lateral extents of 100- and 500-year floods within these drainages.

FLOOD TERMINOLOGY FROM 10 CFR PART 1022

Flood or Flooding: A temporary condition of partial or complete inundation of normally dry land area from the overflow of inland or tidal waters, or the unusual and rapid accumulation or runoff of surface waters from any source.

Floodplain: The lowlands adjoining inland and coastal waters and relatively flat areas and flood-prone areas of offshore islands.

In a related evaluation, DOE determined if the Caliente and Mina rail alignments would cross jurisdictional waters of the United States under Section 404 of the *Clean Water Act* (DIRS 180914-PBS&J 2006, all). Findings from this evaluation that were related to drainage channels on the east side of Yucca Mountain that an alignment would cross were of interest to this assessment. If drainage channels that repository actions affected qualified as waters of the United States, the qualification would not affect the requirements or applicability of including the drainage channels in this assessment. A water of the United States determination simply means that an additional regulatory requirement applies to the applicable channel in that DOE would require a permit from the U.S. Army Corps of Engineers before any fill or excavation could occur in the channel.

According to the waters of the United States evaluation, the Amargosa River is an interstate water and, because Fortymile Wash is a tributary, it is a potential water of the United States under the jurisdiction of the U.S. Army Corps of Engineers (DIRS 180914-PBS&J 2006, p. 4). The washes that drain the east side of Yucca Mountain flow into Fortymile Wash and meet the same criteria for possibly qualifying as waters of the United States. For the last segment of the rail alignment, which would terminate at the Yucca Mountain site, the evaluation identified three ephemeral washes on the east side of Yucca Mountain as potential waters of the United States that the rail alignment would cross. From Figure 3E in the report (DIRS 180914-PBS&J 2006, Appendix A, Figure 3E), the identified crossings appear to include two associated with Busted Butte Wash and one associated with Drill Hole Wash. (The evaluated rail alignment would not go as far north as Midway Valley Wash.) Although these evaluations were specific to the points along the washes where the rail alignment would cross, they imply that, under Corps of Engineers guidelines of the time, washes along the east side of Yucca Mountain as well as Fortymile Wash could qualify as waters of the United States.

On June 5, 2007, the U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers released interim guidance that addresses the jurisdiction over waters of the United States under the *Clean Water Act*. This guidance was a result of Supreme Court decisions that occurred after the DOE evaluation. Based on this guidance, it is likely that the drainages on the east side of Yucca Mountain that DOE currently considers potential waters of the United States might not be considered as such. Before undertaking construction in these washes, DOE would request that the Corps of Engineers determine the limits of jurisdiction under Section 404 of the *Clean Water Act*.

C.1.2 WETLANDS DATA REVIEW

Title 10 CFR Part 1022 requires DOE to determine if the proposed action would affect wetlands and, if necessary, to conduct a wetlands assessment. As required by 10 CFR 1022.11(c), DOE examined the following information in relation to possible wetlands in the vicinity of the Yucca Mountain site:

- *U.S. Fish and Wildlife Service National Wetlands Inventory*. Maps from the National Wetlands Inventory do not identify any naturally occurring wetlands in the vicinity of the Yucca Mountain site (DIRS 147930-FWS 1995, all).

- *U.S. Department of Agriculture, Soil Conservation Service Local Identification Maps*. The Soil Conservation Service (now the Natural Resource Conservation Service) has not conducted a soil survey of the Yucca Mountain site. However, DOE and other agencies have conducted comprehensive surveys and studies of soils at the Yucca Mountain site and in the surrounding area. The surveys indicate that there are no naturally occurring hydric soils at Yucca Mountain [DIRS 104592-CRWMS M&O (1999, pp. 2 to 6)].

- *U.S. Geological Survey Topographic Maps*. Topographic maps of the vicinity (for example, DIRS 147932-USGS 1983, all) do not show springs, permanent streams, or other indications of wetlands.

- *Regional or Local Government-Sponsored Wetlands or Land-Use Inventories*. DOE has conducted a wetlands inventory of the Nevada Test Site (DIRS 101833-Hansen et al. 1997. p. 1-161). The closest naturally occurring wetlands to Yucca Mountain are on the upper west slope of Fortymile Canyon, 6 kilometers (3.7 miles) north of the North Portal and outside the proposed repository construction area.

Based on this information, DOE concluded that a wetlands assessment is not necessary to comply with 10 CFR Part 1022 because there are no wetlands that the Proposed Action could affect.

C.2 Project Description

Under the Proposed Action, the Yucca Mountain site would be the nation's geologic repository and DOE would ship spent nuclear fuel and high-level radioactive waste to the site for a period of up to 50 years. For this analysis, DOE assumed that emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2017 after a 5-year construction period. The discussion that follows has two parts. Section C.2.1 discusses the Proposed Action in the vicinity of the Yucca Mountain site. Section C.2.2 discusses proposed infrastructure improvements that would affect floodplains.

C.2.1 PROPOSED ACTIONS AT YUCCA MOUNTAIN

The preliminary layout of surface facilities in the geologic repository operations area shows these facilities would be in the primary natural drainage channel and associated floodplains of Midway Valley Wash and a short portion of the northern branch of Drill Hole Wash (Figure C-1). Construction of new roads or upgrades to existing roads and possibly placement of the large volumes of excavated rock, or muck, from the subsurface as DOE developed the repository emplacement area would probably affect other washes that drain the east side of Yucca Mountain (Busted Butte Wash and other portions of Drill Hole Wash).

A combination of drainage control features would protect facilities in the geologic repository operations area from flash floods. DOE would build dikes and drainage ditches to surround much of the geologic repository operations area and other associated surface facilities to redirect runoff from outside the area. Exile Hill, although not shown on Figure C-1, is basically a raised rock on the side slope of Yucca Mountain where the North Portal starts. An existing diversion channel on the hill protects the west side of the operations area from runoff from that direction. DOE would integrate the Exile Hill diversion channel into the overall drainage control features. In the operations area, new ditches, improved drainage channels, and storm water detention ponds in the low eastern and southern sides of the diked area would control runoff. Culverts in the dikes would allow storm water in the detention ponds to leave the area in a controlled (throttled) manner to join the natural drainage channel that runs through the gap between Fran Ridge to the south and Alice Hill to the north. From the gap between the two hills, where Midway Valley Wash joins Drill Hole Wash (Figure C-1), drainage would flow to the southeast and south in its current natural course to Fortymile Wash.

Construction in the geologic repository operations area would involve significant earthwork (excavation and filling) to establish the necessary foundations for buildings and the installation of utilities. As noted above, surface-water control measures (ditches, improved channels, storm water ponds, etc.) would be an element of the construction activities. Much of this work would be in, or over, areas shown in Figure C-1 as land where water would otherwise spread during times of flash flooding (that is, in floodplain areas). However, with the planned drainage control features, this would no longer be the case. Because the affected natural drainage channels in this case originate at Yucca Mountain, changes would occur fairly high in the drainage system. The ditches and dikes DOE constructed to keep overland flow out of the operations area would intercept or block relatively minor channels, which are dry most of the time.

The U.S. Geological Survey mapped the 100- and 500-year floodplains of Fortymile Wash and its principal tributaries as described in Section C.1.1 and shown in Figure C-1. DOE used another technique, referred to as the probable maximum flood method [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all)] to estimate maximum flood volumes for specific segments of washes adjacent to planned Yucca Mountain facilities (DIRS 100530-Blanton 1992, all; DIRS 108883-Bullard 1992, all). In more recent studies, DOE has calculated probable maximum flood volumes and associated inundation areas that would result with consideration of tentative locations for surface facilities (DIRS 157928-BSC 2002, all; DIRS 169464-BSC 2004, all). These studies were a means to generate flooding criteria for the more detailed design of these facilities. The probable maximum flood method is widely used in hydrologic designs for structures critical to public safety, and federal regulations require the use of this method for the design of dam spillways, large detention basins, major bridges, and nuclear facilities. The method is a very conservative approach to generate the most severe flood volume reasonably possible for the location under evaluation, which is larger than even the 500-year flood. The 100-year, 500-year, or probable maximum flood would not be high enough to reach the entrances to the subsurface facilities at either the North or South Portal. Studies are currently underway to generate probable maximum flood values for drainage channels near the planned location of the North Construction Portal to ensure that it too would be outside all possible flood levels. Some support facilities outside the North Portal would be in the natural flood zones for the 100-year, 500-year, and the more extensive probable maximum flood. DOE would design drainage control measures to ensure the protection of those surface facilities that are important to safety against all potential floods. DOE would protect other central operations area facilities (those not important to safety) to withstand 100-year floods.

C.2.2 PROPOSED INFRASTRUCTURE ACTIONS

The existing access road to the Yucca Mountain surface facilities crosses about 460 meters (1,500 feet) of Fortymile Wash (Figure C-1) at grade; that is, it is directly on the surface of the wash and does not contain culverts. At this location, the wash contains several braided channels and the occasional floods in Fortymile Wash flow across the road unimpeded. As the water subsides, rock debris in the road can make it impassable until heavy equipment removes the debris.

DOE proposes to replace the existing road where it crosses Fortymile Wash. The new road would be higher and drainage structures would channel floodwaters under the road (DOE would determine roadway and drainage improvements through further design). DOE would design this type of road upgrade to accommodate a 100-year flow, but the final design could consider a range of flood frequencies and a cost-benefit analysis. The culverts and associated dikes and other features that would modify the stream flow would also be designed to minimize erosion upstream and downstream of the crossing. DOE would use heavy earthmoving equipment to construct the road in accordance with standard road construction practices. This equipment would use petroleum-based fuels, oils, lubricants and other hazardous materials, which DOE would store outside the 500-year floodplain (Figure C-1). The Department would obtain construction aggregate from existing borrow pits and concrete from local vendors.

On the west side of Fortymile Wash, the existing access road continues northward about 3.5 kilometers (2.2 miles) to a point where it is next to a 1.5-meter (4.9-foot)-wide ditch that is in the area where Drill Hole Wash and Midway Valley Wash merge and then drain toward Fortymile Wash (Figure C-1). Improvement of the access road could affect the drainage channel in the area, but the effects would be beneficial because DOE would size the drainage area to accommodate flow in the wash more appropriately. The access road from U.S. Highway 95 north to near the Fortymile Wash crossing would also involve segments of new road construction. The new road segments would cross many small washes. Because these washes are small, this assessment does not consider the effects of road construction to their associated floodplains further.

C.3 Existing Environment

Fortymile Wash is about 150 kilometers (93 miles) long and drains an area of about 810 square kilometers (200,000 acres) to the east and north of Yucca Mountain (Figure C-1). The wash continues south and connects to the Amargosa River. The Amargosa River drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa, California. The mostly dry riverbed extends another 100 kilometers (60 miles) before it ends in Death Valley.

Busted Butte Wash and Drill Hole Wash drain the east side of Yucca Mountain and flow into Fortymile Wash (Figure C-1); Midway Valley Wash is a tributary to Drill Hole Wash. Busted Butte Wash drains an area of 17 square kilometers (4,200 acres) and Drill Hole Wash drains an area of 40 square kilometers (9,900 acres).

Chapter 3 of this Repository SEIS describes the existing environment at and near Yucca Mountain, which includes Fortymile, Busted Butte, Drill Hole, and Midway Valley washes. The following sections summarize important aspects of the environment that pertain to this floodplain assessment.

C.3.1 FLOODING

Water flow in the four washes is infrequent. The dry, semiarid climate and meager precipitation [which averages about 10 to 25 centimeters (4 to 10 inches) per year at Yucca Mountain] result in quick percolation of surface water into the ground and rapid evaporation. Flash floods, however, can occur after unusually strong summer thunderstorms or during sustained winter precipitation. During these times, runoff from ridges, pediments, and alluvial fans flows into the normally dry washes that are tributary to Fortymile Wash. Table C-1 lists estimated peak discharges for the base (100-year) and critical action (500-year) floodplains in Fortymile, Busted Butte, and Drill Hole washes.

Table C-1. Estimated peak discharges along washes at Yucca Mountain.

Name	Drainage area (square kilometers)	100-year flood peak discharge (cubic meters per second)	500-year flood peak discharge (cubic meters per second)
Fortymile Wash	810	340	1,600
Busted Butte Wash	17	40	180
Drill Hole Wash[a]	40	65	280

Source: DIRS 102783-Squires and Young 1984, p. 2.

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Includes, as tributaries, Midway Valley Wash in the area of the North Portal and the wash in the area of the South Portal.

The Nevada Test Site access road to Yucca Mountain crosses Fortymile Wash in the area where it is joined by Drill Hole Wash. The next nearest manmade structure in Fortymile Wash is U.S. Highway 95, about 21 kilometers (13 miles) south of the confluence of Drill Hole and Fortymile washes. The portion of the community of Amargosa Valley that was once known as Lathrop Wells is the nearest population center to Yucca Mountain, about 22 kilometers (14 miles) to the south along U.S. Highway 95 and 4.8 kilometers (3 miles) east of Fortymile Wash.

Flooding in the region is often localized. A flash flood in one or more of the washes that drains to Fortymile Wash, for example, might not result in any notable flow in Fortymile Wash. Although infrequent, storm and runoff conditions can be extensive enough to result in flow throughout the drainage system. Glancy and Beck (DIRS 155679-Glancy and Beck 1998, all) documented conditions during March 1995 and February 1998 when Fortymile Wash and the Amargosa River flowed simultaneously through their primary channels to Death Valley. The 1995 incident was the first documented case of this flow condition, though undocumented incidents probably occurred during the preceding 30 years when there were several instances for which records show sections of the primary channels flowing with floodwater.

C.3.2 WETLANDS

There are no springs, perennial streams, hydric soils, or naturally occurring wetlands in the affected areas at Yucca Mountain.

C.3.3 BIOLOGY

Vegetation at and near Fortymile Wash is typical of the Mojave Desert. The mix or association of vegetation in the wash, which is dominated by the shrubs white bursage (*Ambrosia dumosa*), creosote bush (*Larrea tridentate*), white burrobush (*Hymenoclea salsola*), and heathgoldenrod (*Ericameria paniculata*) differs somewhat from other vegetation associations at Yucca Mountain (DIRS 104589-

CRWMS M&O 1998, pp. 5 to 7). No plant species grow exclusively in the floodplains. In addition, none of the more than 180 known plant species at Yucca Mountain is endemic to the area.

No documented mammals, reptiles, or bird species at Yucca Mountain are restricted to or dependent on the floodplains, and these species are widespread throughout the region. Studies have found no amphibians at Yucca Mountain.

The only plant or animal species at Yucca Mountain that the EPA has classified under the *Endangered Species Act* is the desert tortoise (*Gopherus agassizii*), which is threatened. Yucca Mountain is at the northern edge of the range of the desert tortoise (DIRS 101915-Rautenstrauch et al. 1994, p. 11). Desert tortoises occur in the floodplain of Fortymile Wash, but their abundance there and elsewhere at Yucca Mountain is low in comparison to other parts of their range farther south and east (DIRS 102869-CRWMS M&O 1997, pp. 6 to 11). DOE generated *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, p. 2-8), which summarizes information on the ecology of the desert tortoise population at Yucca Mountain.

Several animal and plant species that the Bureau of Land Management or the State of Nevada have classified as sensitive occur at Yucca Mountain (see Section 3.1.51.3 of this Repository SEIS). These species can occur in the floodplains at and near Yucca Mountain, but they are not dependent on habitat there (DIRS 104590-CRWMS M&O 1998, p.8; DIRS 103159-CRWMS M&O 1998, pp. 22 and 23; DIRS 103654-Steen et al. 1997, pp. 19 to 29).

C.3.4 ARCHAEOLOGY

Years of research at and near Yucca Mountain have discovered 830 archaeological sites and that number increases to well over 1,000 when including isolated artifacts, some of which are in Fortymile Wash. These sites range from small scatters of lithic (stone) artifacts to campsites and quarries. They indicate that American Indian populations have occupied the Yucca Mountain region for at least 12,000 years. Fortymile Wash was an important crossroad where several trails converged from such distant places as Owens Valley, Death Valley, and the Avawatz Mountains. A draft programmatic agreement among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Office has been prepared for cultural resources management related to activities that would be associated with development of a repository at Yucca Mountain. While this agreement is in negotiation among the concurring parties, DOE is abiding by Section 106 of the *National Historic Preservation Act of 1966* (16 U.S.C. 470) process.

C.4 Floodplain Effects

Title 10 CFR 1022.12(a)(2) requires a floodplain assessment to discuss the positive and negative, direct and indirect, and long- and short-term effects of a proposed action on an affected floodplain. In addition, the assessment must evaluate the effects on lives and property, and on natural and beneficial values of floodplains. If DOE finds no practicable alternative to the location of activities in floodplains, it will design or modify its actions to minimize potential harm to or in the floodplains. The floodplains DOE assessed are areas of normally dry washes that are temporarily and infrequently inundated from runoff, including during 100-year or more intense (and less frequent) floods. The following sections address effects specific to repository development actions at Yucca Mountain, effects from infrastructure actions, and effects common to both sets of actions.

C.4.1 EFFECTS AT YUCCA MOUNTAIN

Construction of the proposed repository and the associated surface support facilities could affect each of the three primary washes that drain the east side of Yucca Mountain. The most affected would be Midway Valley Wash, which DOE would reroute so it could construct facilities adjacent to the North Portal entrance of the repository and protect them from potential flash flooding. A short portion of the northern branch of Drill Hole Wash (Figure C-1) would be similarly affected (that is, DOE would reroute the natural drainage in this portion of the wash). Road construction and road upgrades would probably affect the other primary washes that drain the east side of Yucca Mountain in this area (Busted Butte Wash and the other portions of Drill Hole Wash), but these effects would occur at crossings with drainage structures, as necessary, or at grade rather than drainage channel reroutes. DOE expansion of existing or new rock storage piles into existing drainage channels could require drainage rerouting for relatively short distances.

DOE would construct facilities for the receipt and management of spent nuclear fuel and high-level radioactive waste close to the North Portal of the repository, which would be the access point to the subsurface area for emplacement of the nuclear waste. The Department would build dikes around this area on the southwest, southeast, and northeast, and around to the north sides. Exile Hill, the location of the North Portal, and an existing drainage channel on the hill would protect the west side from runoff. Outside the diked area, natural drainage channels would carry runoff except in areas where dikes intercepted channels and runoff. In those areas, runoff would flow along the dike until the flow reached another natural drainage point. Runoff would concentrate in the gap between Fran Ridge to the south and Alice Hill to the north, in the same place it now exits the area and drains (via the lower section of Drill Hole Wash) into Fortymile Wash. The main access road into the geologic repository operations area would come through this same gap; DOE would build drainage structures under the road as necessary for runoff to reach the natural drainage channels. Inside the diked portion of the geologic repository operations area, a combination of new ditches and improved channels would manage runoff. They would direct runoff to the low eastern and southeastern portions of the diked area, where storm water detention ponds and culverts would drain accumulated water through the dikes. Water that went though the dikes would join the natural drainage channels to the natural gap and on to Fortymile Wash.

Construction across washes that involved the placement of drainage structures would reduce the area through which floodwaters naturally flow. During large floods, bodies of water could develop on the upstream side of each crossing and slowly drain through drainage structures. This would be an intended result of the design of the dikes and storm water detention ponds in the geologic repository operations area. In the case of road crossings, if the flood occurred quickly and was sufficiently large, water could flow over the road and continue downstream, which could damage the road. Such floods, however would not increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural and beneficial values of floodplains because there are no human activities or facilities upstream or downstream that floods could affect. If runoff or floodwater was held on the upstream side of a drainage feature, there would be a potential for sediment to fall out of the flow and accumulate in the channel. These areas would be subject to periodic maintenance, as necessary, to remove and dispose of accumulated sediment.

C.4.2 EFFECTS FROM INFRASTRUCTURE ACTIONS

The floodplain of Fortymile Wash is normally dry, but runoff, such as would occur during 100- or 500-year floods, can temporarily and infrequently inundate it. Improvement of the existing access road where it crosses Fortymile Wash would reduce the area through which floodwaters naturally flow. During large floods, bodies of water could develop on the upstream side of the crossing and slowly drain through culverts. Such floods, however, would not increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural and beneficial values of the floodplains because there are no nearby human activities or facilities upstream or downstream that they would affect. A sufficiently large flood in Fortymile Wash could create a temporary large lake upstream of the improved road that would slowly drain through the drainage structures. If the flood occurred quickly and was sufficiently large, the dammed water could flow over the road and continue downstream. Some road damage could occur, but the damage would be unlikely to increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural and beneficial values of the floodplains because there are no nearby human activities or facilities downstream that floods would affect.

During flood events, sediment would probably accumulate on the upstream side of the Fortymile Wash crossing. DOE would have to remove this material periodically so future floodwaters would have sufficient space to accumulate, rather than overflow the structures during later smaller floods. When necessary, DOE would remove this material by truck and dispose of it appropriately. Under natural conditions this sediment would have continued downstream and been deposited as the floodwater receded. In comparison to the total amount of sediment that floodwater moves along the entire length of the washes, the amount that accumulated behind the crossing would be small.

During a 100- or 500-year flood, there would be no preferred channels; most channels across the entire width of Fortymile Wash would fill with water (Figure C-1). Therefore, the road would not cause preferential flow in a particular channel or alter the velocity or direction of flow on the floodplain.

C.4.3 EFFECTS COMMON TO BOTH SETS OF ACTIONS

Potential construction across washes and over large areas of a wash, as in the case of Midway Valley Wash, would require the removal of desert vegetation and the disturbance of soil and alluvium. These actions could affect wildlife habitat and individual animals, including the threatened desert tortoise. In 2000, the DOE consulted with the U.S. Fish and Wildlife Service about the effects on the desert tortoise from construction, operations and monitoring, and closure of a repository at Yucca Mountain. The Fish and Wildlife Service concluded in a Biological Opinion in 2001 that it was unlikely that these activities would jeopardize the desert tortoise (DIRS 155970-DOE 2002, Appendix O, pp. 21 to 22). This opinion, and its associated incidental-take provisions, is applicable to the Proposed Action and its alternatives. As directed in the Biological Opinion, DOE would conduct surveys for tortoises or their nests and eggs for avoidance or relocation before surface-disturbing activities, and would perform other mitigation measures delineated in the opinion.

Construction in the floodplains could affect unidentified cultural resources. Before construction, archaeologists would survey the area in accordance with the Programmatic Agreement currently being finalized among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Office. This agreement will address the performance of cultural resources management during the licensing and repository development phases. Cultural resource surveys during previous phases were in accordance with an earlier Programmatic Agreement with the Advisory Council on Historic Preservation (DIRS 104558-DOE 1988, p. 5). DOE would avoid cultural sites if possible or, if that was not possible, would conduct a data recovery program for the sites in accordance with the Programmatic Agreement being negotiated (Section C.3.4). The Department would preserve artifacts from and knowledge about the site. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

Potential indirect impacts on flora and fauna would include increased emissions of fugitive dust, elevated noise levels, and increased human activities. Emissions of fugitive dust would be short-term and unlikely to have a significant effect on vegetation or wildlife. Significant long-term impacts to wildlife from the temporary increase in noise during construction would be unlikely. Wildlife displaced during construction would probably return after the completion of construction.

Periodic maintenance activities, such as sediment removal and drainage structure repair or replacement, would probably have effects similar to those of construction, but generally of smaller magnitude and shorter duration. Before performing maintenance actions, DOE would take measures similar to those described for construction to identify any flora, fauna, or cultural resources of concern and, as appropriate, to identify mitigation measures.

There are no perennial sources of surface water at or downstream from the Yucca Mountain site that the proposed construction activities or periodic maintenance actions would affect.

Construction would not substantially affect the quality or the quantity of groundwater that normally recharges through Fortymile Wash. Water infiltration could increase somewhat after large floods as standing water slowly entered the ground behind crossing or diked areas. The total volume of these water bodies would be a few thousand cubic meters (a few acre-feet) at most, and much of the water would gradually drain through culverts or evaporate before it infiltrated deep into the ground where it might eventually reach the groundwater table about 300 meters (980 feet) below the surface at Fortymile Wash.

DOE would control the use of petroleum fuels, oil, lubricants, and other hazardous materials during construction, would clean up spills promptly and, if necessary, remediate the soil and alluvium. Cleanup and remediation would also occur if there was a hazardous material release during transport to the site on the access road. The small amount of such materials that reached the ground would have little, if any, potential to affect groundwater.

The nearest residents are about 22 kilometers (14 miles) to the south, along U.S. Highway 95 in the community of Amargosa Valley, a few kilometers east of Fortymile Wash. If floodwaters from a 100- or 500-year flood reached this far downstream, there would be no measurable increase in the flood velocity or sediment load attributable to construction for the Yucca Mountain project in comparison to natural conditions. Therefore, disturbances to the floodplains of Fortymile, Busted Butte, Drill Hole, and Midway Valley washes would have no adverse impacts on lives and property downstream. Moreover, impacts to these floodplains would be insignificant in both the short and long terms in comparison to the erosion and deposition that occur naturally and erratically in these washes and floodplains.

During operation of the repository, the fall of a truck or railcar that carried spent nuclear fuel or high-level radioactive waste into Busted Butte, Drill Hole, Midway Valley, or Fortymile washes would be extremely unlikely. However, if this occurred, the shipping casks, which are designed to prevent the release of radioactive materials during an accident, would remain intact. DOE would recover the casks and transport them to the repository. No adverse impacts to surface-water or groundwater quality from such accidents would occur.

DOE has identified no positive or beneficial impacts to the floodplains of Busted Butte, Drill Hole, Midway Valley, or Fortymile washes from the proposed repository and infrastructure actions.

C.5 Mitigation Measures

According to 10 CFR 1022.12(a)(3), DOE must address measures to mitigate the adverse impacts of actions in floodplains, which include but are not limited to minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically sensitive areas. This section discusses floodplain mitigation measures that DOE would consider in the vicinity of Yucca Mountain and, where necessary and feasible, would implement in the washes.

Adverse impacts to the affected floodplains would be small. Even during 100- and 500-year floods, differences in the rate and distribution of erosion and sedimentation caused by the proposed construction would probably not be measurably different from existing conditions. Upgrades to access roads and placement of excavated rock storage piles in the site area would have little effect on erosion and sedimentation from flooding events. DOE would design the drainage structures, dikes, improved channels, and other features it would install to modify stream flow to minimize erosion upstream and downstream. In addition, DOE would follow its reclamation guidelines for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, construction practices, and site maintenance (DIRS 154386-YMP 2001, all). The Department would minimize disturbance of surface areas and vegetation, maintain natural contours to the maximum extent feasible, stabilize slopes to minimize erosion, and avoid unnecessary off-road vehicle travel. Storage of hazardous materials during construction would be outside the floodplains.

Before construction began, DOE would require preconstruction surveys to ensure that the work would not affect sensitive biological or archaeological resources. In addition, these surveys would determine the site's reclamation potential. If construction could threaten important biological or archaeological resources, and modification or relocation of the item under construction or improvement was not reasonable, DOE would incorporate mitigation measures into the design of the work. These measures would include relocation of sensitive species, avoidance of archaeological sites, or data recovery if avoidance was not feasible. In that case, DOE would evaluate the cultural resources for their importance and eligibility for inclusion in the *National Register of Historic Places*, and would collect and document artifacts at eligible sites in accordance with Section 106 of the *National Historic Preservation Act* and the Programmatic Agreement negotiated between DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Office (Section C.3.4). In the years after construction, DOE would take similar actions before any maintenance to determine if work could affect sensitive biological resources that might have moved back into the area or newly identified archeological resources.

If there were spills of hazardous materials during construction of the facilities and roads or during transport to the repository, DOE would quickly clean the spill and remediate the soil and alluvium.

Storage of hazardous materials would be away from floodplains to decrease the probability of an inadvertent spill in these areas.

C.6 Alternatives

According to 10 CFR 1022.12(a)(3), DOE must consider alternatives to its proposed action. DOE has addressed alternatives in relation to sites for surface construction for both the repository and infrastructure upgrades.

C.6.1 ALTERNATIVES TO ACTIONS AT YUCCA MOUNTAIN

The long history of alternatives that DOE has considered has led to the Proposed Action at Yucca Mountain. The geologic disposal of radioactive waste has been the focus of more than 40 years of scientific research. After an extensive consideration of options, Congress enacted the NWPA, which specified that DOE will dispose of spent nuclear fuel and high-level radioactive waste underground in deep geologic repositories. In the 1987 amendments to the NWPA, Congress directed DOE to study only Yucca Mountain to determine its suitability as a repository. On July 9, 2002, Congress passed a joint resolution that approved Yucca Mountain as the site for development of a geologic repository. As a result, the only alternative to the Proposed Action that DOE considered in the 2002 Yucca Mountain FEIS and this Repository SEIS is the No-Action Alternative. Under the No-Action Alternative, DOE would avoid additional impacts or effects on floodplains at and near Yucca Mountain, but would not meet its legal obligation to develop a repository.

In the framework of repository development, DOE could have designed a surface facility layout with less disturbance to existing drainage channels and floodplains than that described in this assessment. However, avoidance of all effects to floodplains is unreasonable. DOE will base its ultimate design of surface facilities and their exact layouts on optimization of the efficiency of those facilities in the performance of their functions and, more importantly, in the protection of the health and safety of the people who would work in those facilities and adjacent areas. Given the relatively minor effects on floodplains from the Proposed Action, protection of the health and safety of the workers and a facility layout that optimizes their efficiency are more significant criteria. There is no practicable alternative that would affect floodplains less.

C.6.2 ALTERNATIVES TO INFRASTRUCTURE ACTION

To operate a repository at Yucca Mountain, DOE would require a road that crossed Fortymile Wash to access facilities west of the wash. Consideration of a new access road across the wash is unreasonable if the existing road, if improved, would adequately meet DOE operational needs. Moreover, a new access road across the wash at a different location would increase environmental damage and costs. Because of these concerns, DOE eliminated a new access road across the wash from detailed consideration.

Selection of the No-Action Alternative would avoid additional impacts to Fortymile Wash. DOE could use the existing road, but this alternative would not meet the Department’s operational needs.

C.7 Floodplain Statement of Findings

Consistent with the presentations in this assessment, this section contains a preliminary Floodplain Statement of Findings for those actions at the Yucca Mountain site and for the infrastructure actions that would affect only Fortymile Wash. Pending results of the public comment period for the Draft Repository SEIS, DOE intends to finalize the Statement of Findings below, or a similar one, in the Final Repository SEIS.

C.7.1 PRELIMINARY STATEMENT OF FINDINGS FOR ACTIONS AT YUCCA MOUNTAIN

Facilities that DOE would build at the Yucca Mountain site would encroach on the primary natural drainage channel and associated floodplains of Midway Valley Wash and a short portion of the northern branch of Drill Hole Wash. Construction of new roads or upgrades to existing roads and possible placement of the large volumes of excavated rock from the subsurface would probably affect other washes that drain the east side of Yucca Mountain (Busted Butte Wash and portions of Drill Hole Wash). Since Yucca Mountain has been designated as the site for development of a geologic repository, DOE believes that there are no practicable alternatives to the locations of facilities, roads, and materials in floodplains at the Yucca Mountain site. The ultimate design and layout of surface facilities will optimize the efficiency of their functions and protect the health and safety of workers. DOE would avoid floodplains associated with the normally dry drainage channels at Yucca Mountain to the extent these other criteria would not be jeopardized.

Construction of new facilities and roads and upgrades to existing facilities and roads would affect floodplains in the vicinity of the Yucca Mountain site. To provide adequate protection for these facilities from flash flooding, DOE would dike areas and reroute natural drainage channels. In areas where roads crossed existing washes, the Department would generally install drainage structures (unless the crossing was at grade); construction activities could reduce the area through which floodwaters naturally flow. However, none of these impacts would be likely to increase the risk of future flood damage, increase the impact of floods on human health and safety, or harm the natural and beneficial values of the floodplains because there are no human activities or facilities upstream or downstream that floods could affect.

The No-Action Alternative would avoid additional impacts or effects on floodplains at and near Yucca Mountain, but would not achieve DOE’s legal obligation under the NWPA to develop a repository for the nation’s spent nuclear fuel and high-level radioactive waste.

During construction and operations at the Yucca Mountain site, DOE would avoid disturbance of sensitive species, cultural resources, and floodplains whenever possible. If avoidance was not practicable, the Department would use standard mitigation practices to minimize the potential impacts to floodplains. Procedures would include preconstruction and biological surveys to identify and relocate sensitive species; avoidance of archaeological sites (or data recovery if avoidance was not feasible); modification of designs and implementation of good engineering practices such as minimizing the size of disturbance areas, topsoil salvage, preservation of natural contours, and surface erosion or runoff control; reclamation and revegetation of disturbed areas; and use of established guidelines for hazardous materials storage and response to a spill.

DOE would construct some surface facilities in floodplains in accordance with all applicable requirements, which include state or local floodplain protection standards. If Busted Butte Wash, Drill Hole Wash, or Midway Valley Wash qualified as a jurisdictional water of the United States, the Department would obtain the appropriate permit, or permits, from the U.S. Army Corps of Engineers for actions in those washes. DOE would base its planning and actions on consultations with the Corps of Engineers.

C.7.2 PRELIMINARY STATEMENT OF FINDINGS FOR INFRASTRUCTURE ACTIONS

Effects to the floodplain of Fortymile Wash would occur from improvements to the existing access road where it crosses Fortymile Wash. Construction activities could reduce the area through which floodwaters naturally flow. However, none of these actions would be likely to increase the risk of future flood damage, increase the impact of floods on human health and safety, harm the natural and beneficial values of the floodplains because there are no nearby human activities or facilities upstream or downstream that floods could affect. There are no delineated wetlands at or near Yucca Mountain.

Under the No-Action Alternative, no new impacts to the floodplain of Fortymile Wash would occur, but DOE would not meet its operational needs.

During construction and upgrade activities, DOE would use standard mitigation practices to minimize potential impacts to the floodplain of Fortymile Wash. Procedures would include preconstruction surveys to identify and, if necessary, relocate sensitive species and avoid cultural sites; modification of designs and implementation of good engineering practices such as minimizing the size of disturbances, topsoil salvage, preserving natural contours, and controlling surface erosion and runoff; reclaiming and revegetating disturbed areas; and use of established guidelines for hazardous materials storage and response to accidental spills.

DOE would perform its proposed infrastructure actions in the floodplain of Fortymile Wash in accordance with all applicable requirements, which include state or local floodplain protection standards. If Fortymile Wash qualified as a jurisdictional water of the United States, DOE would obtain the appropriate permit from the U.S. Army Corps of Engineers for the action. DOE would base its planning and actions on consultations with the Corps of Engineers.

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Appendix D

Radiological Health Impacts Primer and Estimation of Preclosure Radiological Health Impacts

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D. RADIOLOGICAL HEALTH IMPACTS PRIMER AND ESTIMATION OF PRECLOSURE RADIOLOGICAL HEALTH IMPACTS

This appendix contains information that supports the estimates of preclosure human health and safety impacts in this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS). Preclosure impacts would occur during construction, operations and monitoring, and closure of the proposed repository. (Chapter 5 and Appendix F discuss postclosure repository performance; Appendix E discusses potential radiological impacts of accidents.)

Section D.1 is a primer that explains the nature of radiation, the origin of radiation in the context of radiological impacts, and how radiation interacts with the human body to produce health impacts. Section D.2 describes releases of radiological materials to the atmosphere that would affect involved and noninvolved workers and the public. Section D.3 describes the affected populations of these groups and the hypothetical maximally exposed workers and members of the public among those populations. Section D.4 discusses the methodology and data this analysis used to estimate occupational and public health impacts and presents the detailed results.

D.1 Radiological Health Impacts Primer

This section discusses the concepts of human health impacts as a result of exposure to radiation.

D.1.1 RADIATION

Radiation is the emission and propagation of energy through space or through a material in the form of waves or bundles of energy called photons or in the form of high-energy subatomic particles. Radiation generally results from atomic or subatomic processes that occur naturally.

The most common kind of radiation is electromagnetic radiation, which consists of photons. Electromagnetic radiation occurs over a range of wavelengths and energies. We are most commonly aware of visible light, which is part of the spectrum of electromagnetic radiation. Types of radiation of longer wavelengths and lower energy include infrared, which heats an exposed material, and radio waves. Types of electromagnetic radiation of shorter wavelengths and higher energy (which are more penetrating) include ultraviolet, which causes sunburn, and x-rays and gamma radiation.

Ionizing radiation is radiation that has sufficient energy to displace electrons from atoms or molecules to create ions. It can be electromagnetic (for example, x-rays or gamma radiation) or subatomic particles (for example, alpha, beta, or neutron radiation). The ions have the ability to interact with other atoms or molecules; in biological systems, this interaction can cause damage in the tissue or organism.

D.1.2 RADIOACTIVITY

Radioactivity is the property or characteristic of an unstable atom to undergo spontaneous transformation (to disintegrate or decay) with the emission of energy as radiation. The emitted radiation is usually ionizing. The result of radioactive decay is the transformation of an unstable atom (a radionuclide) into a different atom, which releases energy (as radiation) as it reaches a more stable, lower energy configuration.

Radioactive decay produces three main types of ionizing radiation—alpha particles, beta particles, and gamma or x-rays. Each of these types can have different characteristics and levels of energy and therefore different abilities to penetrate and interact with atoms in the human body. Because each type has different characteristics, each requires different amounts of material to stop (or shield) the radiation. Alpha particles are the least penetrating; a thin layer of material such as a single sheet of paper stops them. However, if radioactive atoms (called radionuclides) emit alpha particles inside the body when they decay, there is a concentrated deposition of energy near the point where the decay occurs. Shielding beta particles requires thicker layers of material such as several reams of paper or several centimeters of wood or water. Shielding from gamma rays, which are highly penetrating, requires several centimeters to several meters of heavy material (for example, concrete or lead). A gamma ray disperses energy along the line of passage through the body in contrast to the local energy deposition by an alpha particle. Some gamma radiation can pass through the body without interaction. Shielding from neutrons, which are also highly penetrating, requires materials that contain light elements such as hydrogen.

In a nuclear reactor, heavy atoms such as uranium and plutonium can undergo another process, called fission, after the absorption of a subatomic particle (usually a neutron). In fission, a heavy atom splits into two lighter atoms and releases energy in the form of radiation and the kinetic energy of the two new lighter atoms. These lighter atoms are called fission products. The fission products are usually unstable and undergo radioactive decay toward a more stable state.

Some of the heavy atoms might not fission after they absorb a subatomic particle. A new nucleus forms instead that tends to be unstable (like fission products) and undergo decay.

The decay of fission products and unstable heavy atoms is the source of the radiation from spent nuclear fuel and high-level radioactive waste that makes these materials hazardous in terms of potential human health impacts.

D.1.3 EXPOSURE TO RADIATION AND RADIATION DOSE

Radiation that originates outside the body is external or direct radiation. Such radiation can come from an x-ray machine or from radioactive materials that directly emit radiation, such as radioactive waste or radionuclides in soil. Shielding, such as lead, between the source of the radiation and the exposed individual can reduce or eliminate the exposure. Internal radiation originates inside a person’s body after an intake of radioactive material through ingestion or inhalation. Once the material is in the body, its chemical behavior and how the body metabolizes it affects the potential for damage to the body. If the material is soluble, bodily fluids might dissolve it, transport it to various body organs, and deposit it there. If the material is insoluble, it might move rapidly through the gastrointestinal tract if it was ingested or deposit in the lungs if it was inhaled.

Exposure to ionizing radiation is expressed in terms of absorbed dose, which is the amount of energy that is imparted to matter per unit mass. Often simply called dose, it is a fundamental concept in the measurement and quantification of the effects of exposure to radiation. The unit of absorbed dose is the rad. The different types of radiation have different effects in damage to cells of biological systems. With the use of a radiation-specific quality factor, the dose equivalent concept accounts for the absorbed dose and the relative effectiveness of the type of ionizing radiation damage to biological systems. The unit of dose equivalent is the rem.

There are several additional concepts in the quantification of the effects of radiation on humans. The effective dose equivalent method quantifies effects of radionuclides in the body through estimation of the susceptibility of the different tissues in the body to radiation to produce a tissue-specific weighting factor, which is based on the susceptibility of that tissue to cancer. The unit of effective dose equivalent is the rem. The sum of the products of each affected tissue's estimated dose equivalent multiplied by its specific weighting factor is the effective dose equivalent for a particular type of exposure. The potential effects from a one-time ingestion or inhalation of radioactive material are calculated over a period of 50 years to account for radionuclides that have long half-lives and long residence times in the body. The result is the committed effective dose equivalent. Total effective dose equivalent is the sum of the committed effective dose equivalents from radionuclides in the body plus the dose equivalent from radiation sources external to the body. All estimates of radiation dose in this Repository SEIS, unless specifically noted otherwise, are total effective dose equivalents in rem or millirem.

More detailed information on the concepts of radiation dose and dose equivalent is available in Report 115 from the National Council on Radiation Protection and Measurements (DIRS 101857-NCRP 1993, all) and Publication 60 from the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, all).

The factors for conversion of estimates of radionuclide intake (by inhalation or ingestion) or external exposure to radionuclides [by groundshine or cloudshine (immersion)] to radiation dose are dose conversion factors or dose coefficients. The International Commission on Radiological Protection and federal agencies such as the U.S. Environmental Protection Agency (EPA) publish these factors (DIRS 172935-ICRP 2001, all; DIRS 175544-EPA 2002, all), which are based on original recommendations of the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from International Commission on Radiological Protection Publication 72 (DIRS 152446-ICRP 1996, all).

The radiation dose to an individual or to a group of people can be expressed as the total received dose or as a dose rate, which is dose per unit time (usually an hour or a year). Population dose is the total dose to an exposed population; person-rem is the unit. Population dose (or collective dose) is the sum of the individual dose to each member of a population. For example, if 100 workers each received 0.1 rem, the population dose would be 10 person-rem.

D.1.4 BACKGROUND RADIATION

Nationwide, on average, members of the public receive approximately 360 millirem per year from natural and manmade sources (DIRS 101855-NCRP 1987, p. 53). About 60 millirem per year are from medical radiation and consumer products. About 300 millirem are from natural sources (DIRS 100472-NCRP 1987, p. 149). The largest natural sources are radon-222 and its radioactive decay products in homes and buildings, which contribute about 200 millirem per year. Additional natural sources include radioactive material in the earth (primarily the uranium and thorium decay series and potassium-40) and cosmic rays from space that make it through the atmosphere. In relation to exposures from human activities, the combined doses from weapons testing fallout, consumer and industrial products, and air travel (cosmic radiation) account for the remaining approximately 3 percent of the total annual dose. Nuclear fuel-cycle facilities contribute 0.05 millirem per year, less than 0.1 percent of the total dose.

D.1.5 IMPACTS TO HUMAN HEALTH FROM EXPOSURE TO RADIATION

Exposures to radiation or radionuclides are often characterized as being acute or chronic. Acute exposures occur over a short period, typically 24 hours or less. Chronic exposures occur over longer periods (months to years) and are usually continuous over the period, even though the dose rate might vary. For a given dose of radiation, chronic exposure is usually less harmful than acute exposure because the dose rate (dose per unit time, such as rem per hour) is lower, which provides more opportunity for the body to repair damaged cells.

D.1.5.1 Acute Exposures at High Dose Rates

Exposures to high levels of radiation at high dose rates over a short period (less than 24 hours) can result in acute radiation effects. Minor changes in blood characteristics might occur at exposures in the range of 25 to 50 rad. The external symptoms of radiation sickness begin to appear following acute exposures of about 50 to 100 rad and can include anorexia, nausea, and vomiting. More severe symptoms occur at higher doses and can include death at doses higher than 200 to 300 rad of total body irradiation, depending on the level of medical treatment. Information on the effects of acute exposures on humans is the result of studies of the survivors of the Hiroshima and Nagasaki bombings and from studies after a number of accidental acute exposures.

Acute exposures have occurred after detonations of nuclear weapons in wartime and during weapons testing, and in other events that involved testing of nuclear materials. In addition, there is a potential for acute exposures in the event of an accident at an operating nuclear power plant, although U.S. Nuclear Regulatory Commission (NRC) regulations require plant designs that make such events extremely unlikely. Such exposures could occur only if a highly unlikely failure of the containment vessel around the nuclear reactor occurred with a large release of fission products.

In contrast, accidents during the shipment of spent nuclear fuel or high-level radioactive waste do not have the potential to release sufficient fission products to cause acute exposures that could immediately threaten the life of workers or the public. The fission product source term in the spent nuclear fuel would have decayed by a factor of 10,000 or more by the time the U.S. Department of Energy (DOE or the Department) shipped the material to the proposed repository. Therefore, there would not be sufficient energy in the fission products in the spent nuclear fuel and high-level radioactive waste to melt the fuel elements and vaporize fission products, as NRC has postulated for an accident at an operating nuclear power plant.

D.1.5.2 Chronic Exposures at Low Dose Rates

The analysis for this Repository SEIS assumed all doses would be at low dose rates. Such exposures can be chronic (continuous or nearly continuous), such as those cask handlers and health physics technicians would receive. In some instances, exposures to low levels of radiation would be intermittent (for example, infrequent exposures to persons along the transportation routes DOE would use to ship spent nuclear fuel and high-level radioactive waste to the proposed repository). Cancer induction is the principal potential risk to human health from exposure to low levels of radiation. The estimation of cancer induction is a statistical process in that exposure to radiation conveys only a chance of incurring cancer, not a certainty. Further, cancer induction in individuals can occur from other causes, such as exposure to chemical agents.

D.1.6 DOSE-TO-HEALTH EFFECT CONVERSION FACTORS

Cancer is the principal potential risk to human health from exposure to low or chronic levels of radiation. Radiological health impacts are expressed as the incremental changes in the number of expected fatal cancers (latent cancer fatalities) for populations and as the incremental increases in the lifetime probability of an individual contracting a fatal cancer. The estimates are based on the received dose and on dose-to-health-effect conversion factors that were recommended by the Interagency Steering Committee on Radiation Standards (DIRS 174559-Lawrence 2002, all) and by current DOE guidance (DIRS 178579-DOE 2004, pp. 22 to 24). The Steering Committee consists of eight federal agencies (EPA, NRC, DOE, the U.S. Department of Defense, the U.S. Department of Homeland Security, the U.S. Department of Transportation, the Occupational Safety and Health Administration, and the U.S. Department of Health and Human Services), three federal observer agencies (the Office of Science and Technology Policy, the Office of Management and Budget, and the Defense Nuclear Facilities Safety Board), and observer agencies from two states (Illinois and Pennsylvania). The Committee estimated that, for the general population and workers, a population dose of 1 person-rem would yield 0.0006 excess latent cancer fatality.

Sometimes, calculations of the number of latent cancer fatalities in relation to dose do not yield whole numbers and, especially in environmental applications, can yield values less than 1. For example, if each individual in a population of 100,000 received a total radiation dose of 0.001 rem, the population dose would be 100 person-rem and the corresponding estimated number of latent cancer fatalities would be 0.06 (100,000 persons × 0.001 rem × 0.0006 latent cancer fatalities per person-rem). How should one interpret a nonintegral number of latent cancer fatalities, such as 0.06? The answer is to interpret the result as a statistical estimate; that is, 0.06 is the average number of latent cancer fatalities that would result if the same exposure situation occurred to many different groups of 100,000 people. For most groups, no one would incur a latent cancer fatality from the 0.001-rem radiation dose each member had received. In a small fraction of the groups (about 6 percent), 1 latent cancer fatality would result, and in exceptionally few groups, 2 or more latent cancer fatalities would occur. The average number of latent cancer fatalities for all the groups would be 0.06. The most likely outcome for any single group is no latent cancer fatalities.

D.1.7 COMPARISON WITH OTHER DOSE-TO-HEALTH EFFECT CONVERSION FACTORS

The dose-to-health effect conversion factor recommended by the Interagency Steering Committee on Radiation Standards is higher than that in the analysis for the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS). The FEIS used 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (DIRS 155970-DOE 2002, p. 3-97). The recommended dose-to-health effect conversion factor of 0.0006, which this Repository SEIS uses, is similar to the lethality-adjusted cancer risk coefficients from the International Commission on Radiological Protection of 0.00041 per person-rem for workers and 0.00055 per person-rem for individuals among the general population (DIRS 182836-ICRP 2007, p. 25). It is also similar to the conversion factors from the National Research Council in *Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII Phase 2* (DIRS 181250-National Research Council 2006, p. 15), which range from 0.00041 to 0.00061 latent cancer fatality per person-rem for solid cancers and 0.00005 to 0.00007 latent cancer fatality per person-rem for leukemia, and the age-specific dose-to-health effect conversion factor of 0.000575 latent cancer fatality per person-rem from the EPA (DIRS 153733-EPA 2000, Table 7.3, p. 179).

D.1.8 LINEAR NO-THRESHOLD MODEL

The premise of the linear no-threshold model is that there is some risk, even at the lowest radiation doses. The Committee on the Biological Effects of Ionizing Radiation reviewed the linear no-threshold model (DIRS 181250-National Research Council 2006, p. 9). The Committee examined arguments that low doses of radiation are more harmful than the linear no-threshold model suggests, and it concluded that radiation health effects research, as a whole, does not support this view.

D.1.9 RADIATION HORMESIS

The premise of radiation hormesis is that a threshold or decrease in effect exists at low radiation doses, and that use of the linear no-threshold model exaggerates the health effects of low levels of ionizing radiation. The Committee on the Biological Effects of Ionizing Radiation reviewed the issue of radiation hormesis (DIRS 181250-National Research Council 2006, pp. 9 to 10). The Committee did not accept the hypothesis that the risks are lower than the linear no-threshold model predicts, that they are nonexistent, or that low doses of radiation could even be beneficial. The Committee concluded that there is always some risk, even at low doses.

D.1.10 OTHER RADIATION HEALTH EFFECTS

Table D-1 lists other health effects such as nonfatal cancers and genetic effects that can occur as a result of chronic exposure to radiation. The International Commission on Radiological Protection evaluated these other health effects (DIRS 182836-ICRP 2007, p. 25).

Table D-1. Detriment-adjusted nominal risk coefficients for cancer and heritable effects from exposure to radiation.

Population	Cancer (per rem)	Heritable effects (per rem)	Total (per rem)
Whole population	5.5×10^{-4}	2×10^{-5}	6.0×10^{-4}
Adults	4.1×10^{-4}	1×10^{-5}	4.0×10^{-4}

Source: DIRS 182836-ICRP 2007, p. 25.
Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.

The dose-to-health-effect conversion factors for cancer in Table D-1, 0.00041 per person-rem for workers and 0.00055 per person-rem for individuals among the general population, are based on cancer incidence data but include consideration of cancer lethality and life impairment. In addition, Table D-1 lists dose-to-health-effect conversion factors for heritable effects—0.00001 per person-rem for workers and 0.00002 per person-rem for individuals among the general population. The total detriment, 0.0004 per person-rem for workers and 0.0006 per person-rem for individuals among the general population, is consistent with the recommended factor of 0.0006. While DOE recognizes the existence of health effects other than fatal cancers, it has chosen to quantify the impacts in this Repository SEIS in terms of latent cancer fatalities, in part because the other health effects are a small portion of the total detriment from exposure to radiation.

Radiation exposure increases the risk of other diseases, particularly cardiovascular disease, in persons who receive high therapeutic doses and in atomic bomb survivors and others who receive more modest doses.

The Committee on the Biological Effects of Ionizing Radiation reviewed the issue of health effects other than cancer (DIRS 18125-National Research Council 2006, p. 8). The Committee concluded that there was no direct evidence of increased risk of noncancer diseases at low doses and that data were inadequate to quantify this risk if it exists. Radiation exposure increases the risk of some benign tumors, but the Committee concluded that data were inadequate to quantify this risk.

D.1.11 PRENATAL EXPOSURE

Studies of prenatal exposure or exposure in early life to diagnostic x-rays have shown that there is a significantly increased risk of leukemia and childhood cancer from a diagnostic dose of 1 to 2 rem to the embryo or fetus in utero. In recognition of this, DOE and NRC regulations (10 CFR 835.206 and 10 CFR 20.1208, respectively) specifically address protection of declared pregnant workers from radiation, in which they limit the exposure of the embryo or fetus to 0.5 rem during the period from conception to birth.

D.2 Atmospheric Releases of Radioactive Materials

There would be two major types and sources of radionuclide releases to the air from project activities at the proposed repository. The ventilation exhaust air from the subsurface facility would contain naturally occurring radon-222 and its decay products during all periods (Section D.2.1). Handling and transfer of commercial spent nuclear fuel in the surface Wet Handling Facility during operations would release manmade radioactive materials (Section D.2.2). There would be other minor sources of release from the subsurface repository: neutron activation of ventilation air in the emplacement drifts and release of neutron-activated rock dust to the air from the emplacement drift walls (Section D.2.3). As indicated in Section D.5.1, almost all (99.9 percent) of the potential health impacts to the public would be from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air.

D.2.1 RELEASE OF RADON-222 AND RADON DECAY PRODUCTS FROM THE SUBSURFACE FACILITY

In the subsurface facility radon-222 would diffuse continuously from the rock into the air. Radioactive decay of the radon would produce radon decay products during transport through the ventilation system. The primary radionuclide members of the radon-222 decay chain are polonium-218, lead-214, and bismuth-214. Exhaust ventilation air would carry the radon-222 and the radon decay products that originated from the host rock. For this analysis, DOE based the estimates of radon-222 releases and radon decay product concentrations in the subsurface facility on concentration data from the Exploratory Studies Facility and the concentration calculation results for a fully developed repository (DIRS 164380-BSC 2003, all; DIRS 167021-BSC 2003, all).

In calculating radon releases over time, the analysis assumed that the releases would increase linearly over the 5-year construction period and 22 years of construction and operations at the beginning of the 50-year operations period. The maximum annual radon release would begin after the completion of excavation, last the final 28 years of the operations period, and continue through the monitoring period. During the monitoring period, forced ventilation would continue at the same rate, as would the radon release rate. Monitoring and maintenance activities would last for 50 years. Releases of radon and its decay products during the closure period duration of 10 years would decrease linearly as crews gradually sealed openings. The initial release rate would be the same as that of the monitoring period and would decrease to none. Figure D-1 shows the estimated radon release rate as a function of time.

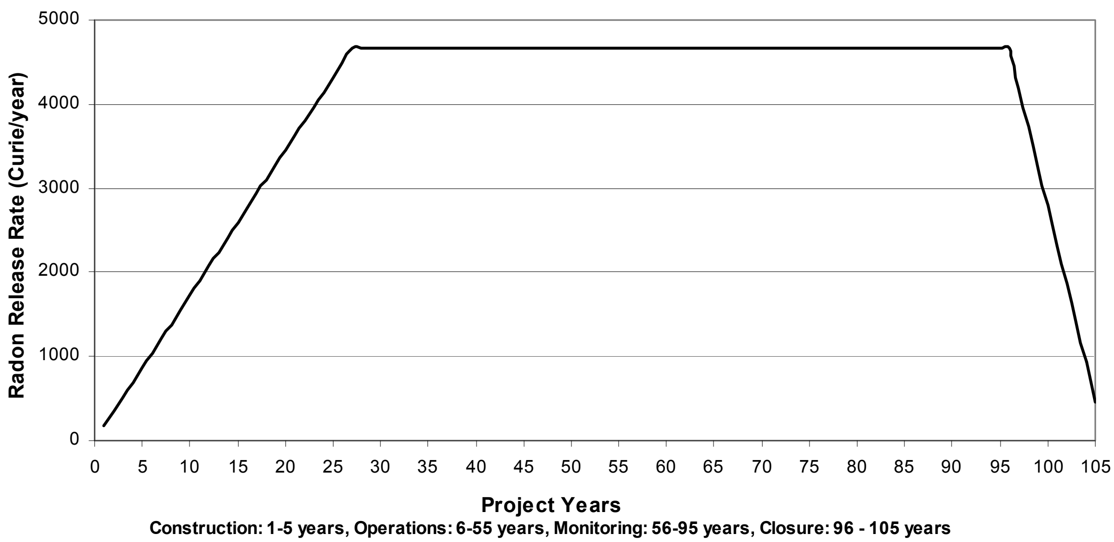

Figure D-1. Radon release rate as a function of time.

D.2.2 RELEASES OF RADIONUCLIDES FROM SURFACE FACILITIES

As explained in Chapter 2 of this Repository SEIS, DOE assumed that 90 percent of the commercial spent nuclear fuel would arrive at the proposed repository in transportation, aging, and disposal (TAD) canisters. Most DOE spent nuclear fuel and high-level radioactive waste would arrive in disposable canisters. The only exception would be DOE spent nuclear fuel of commercial origin, which could arrive uncanistered. None of the canisters of DOE materials would require opening at the repository; workers would place them directly into waste packages. Therefore, releases from these canisters during normal operations would not occur. About 10 percent of the commercial spent nuclear fuel would arrive at the repository either as uncanistered fuel or in dual-purpose canisters. Nondisposable canisters would require opening in the Wet Handling Facility, where workers would handle uncanistered spent nuclear fuel and nondisposable canisters using remote-control equipment underwater to load the fuel into TAD canisters for eventual placement in a waste package.

Commercial spent nuclear fuel contains encapsulated uranium, transuranic elements, fission products, and activation products in the structural materials of the fuel assemblies or as crud on the exterior of the fuel assemblies. Small amounts of these radioactive materials would be released into the pool of the Wet Handling Facility and the exhaust ventilation air. The water would capture most of the materials, which would become part of the low-level radioactive waste stream that DOE would manage as described in Chapter 4, Section 4.1.12 of this Repository SEIS. The materials that entered the exhaust ventilation air would be filtered, but the radioactive gasses and a small percentage of the particulates in the canisters or shipping containers would be released to the atmosphere under normal operating conditions.

The Wet Handling Facility, which would process about 10 percent of the commercial spent nuclear fuel, would be the only surface facility with the potential to release radioactive materials to the environment during normal operations. The other surface facilities would handle only sealed canisters, and therefore would not release airborne radioactive materials under normal operating conditions. The sources of radioactive materials from the Wet Handling Facility would include cask venting and fuel failures during handling and temporary staging. The following sections describe the assumptions and methods for estimation of these releases.

D.2.2.1 Characteristics of Spent Nuclear Fuel

Airborne releases during normal operations would only occur in the Wet Handling Facility during processing of uncanistered fuel and fuel from dual-purpose canisters. Because 90 percent of the waste stream would be received in TAD canisters, potential airborne releases would be only from the remaining portion of the waste stream. To estimate the magnitude of the radioactive releases from the Wet Handling Facility, the analysis conservatively assumed that all commercial spent nuclear fuel would consist of the same composition of radionuclides. This composition represents the design-basis fuel characteristics, and the analysis based it on a 4-percent (maximum) initial enrichment of uranium-235 in a large pressurized-water reactor with burnup of 60,000 megawatt-days per metric ton of heavy metal (MTHM) and a cooling (or aging) time of 10 years after removal from the reactor (DIRS 161120-BSC 2002, Section 5.5). The radiation intensity of this fuel bounds approximately 97 percent of the fuel that DOE would dispose of at the proposed repository (DIRS 161120-BSC 2002, Section 5.5.1). Use of the design-basis fuel characteristics also bounds the representative commercial spent nuclear fuel characteristics developed for repository preclosure normal operations radiological impact analysis; which based it on a pressurized-water reactor fuel assembly with 4.2-percent initial enrichment, 50,000 megawatt-days per MTHM burnup rate, and 10 years cooling time (DIRS 180185-BSC 2007, Section 7). The radionuclide composition of this design-basis fuel, therefore, represents a conservative approach for estimation of the potential release source terms during normal operations.

D.2.2.2 Release Parameters

DOE based the parameters for release estimates primarily on NRC guidance and the use of data and experience from operating nuclear power plants. Releases of gases and materials from a spent nuclear fuel rod would occur only in the event of fuel failures in which the cladding of the fuel cracked or leaked. NRC guidance indicates that less than 1 percent of commercial spent nuclear fuel would have failed fuel rods (DIRS 149756-NRC 2000, p. 9-12; DIRS 160582-NRC 2003, Attachment, Table 7.1). To estimate crud releases, the analysis assumed 15 percent of the crud surface activity would become loose from the fuel surfaces and 10 percent of the loose crud would become airborne during normal operations. The 15-percent loose fraction is from NRC guidance (DIRS 149756-NRC 2000, p. 9-12; DIRS 160582-NRC 2003, Attachment, Table 7.1). The 10-percent airborne release fraction is the bounding release fraction for the case in which venting gases pressurized the volume in which loose powdering surface contamination existed (DIRS 103756-DOE 1994, p. 5-22). Table D-2 lists the radionuclide release fractions. Each fraction, except that for crud, is the fraction of the total radionuclide inventory in a

Table D-2. Airborne release fractions by radionuclide group.

Radionuclide group	Spent nuclear fuel nuclide	Release fraction[a]
Gases	Hydrogen-3 Carbon-14 Chlorine-36 Krypton-85 Iodine-129	0.3
Volatiles	Cesium-134 Cesium-137	0.0002
Crud	Cobalt-60 Iron-55	0.015[b]
Fuel fines	Particulates	0.00005

a. Source: DIRS 149756-NRC 2000, p. 9-12; DIRS 160582-NRC 2003, Attachment, Table 7.1.
b. Source: DIRS 149756-NRC 2000, p. 9-12; DIRS 160582-NRC 2003, Attachment, Table 7.1; DIRS 103756-DOE 1994, p. 5-22.

commercial spent nuclear fuel rod; the fractions are applicable only to the failed fuel rods in a fuel assembly.

The analysis used the release fractions, a decontamination factor of 10,000 for a two-stage high-efficiency particulate air filter system in the Wet Handling Facility, the analyzed schedule of receipts, and the design capacity of the Wet Handling Facility to estimate the amount of radionuclides that handling activities would release to the environment as a result of normal operations. Table D-3 lists the radionuclide releases for an annual throughput of 3,000 MTHM of commercial spent nuclear fuel; 10 percent of this amount (300 MTHM per year) would require handling in the Wet Handling Facility. The listed radionuclides are those the analysis determined to be important for dose calculation based on the selection criteria in NRC guidance (DIRS 149756-NRC 2000, p. 9-11; DIRS 160582-NRC 2003, Attachment, Section 3). These nuclides represent more than 99.7 percent of the total radionuclide source term activity and contribute more than 99.9 percent of the calculated offsite dose from the release of manmade radionuclides. The table includes all gaseous nuclides.

D.2.3 AIRBORNE RELEASES FROM SUBSURFACE FACILITY

During normal operations of the subsurface repository, in addition to the continuous release of radon-222 through the ventilation exhaust, two potential mechanisms could generate additional airborne releases of radioactive materials: neutron activation of ventilation air in the emplacement drifts and release of neutron activated rock dust to the air from the emplacement drift walls. Table D-3 lists the estimated annual releases of radionuclides from the subsurface facility under normal operating conditions (DIRS 172487-BSC 2005, pp. 33 to 35).

The principal pathways by which airborne radioactivity from the repository could reach workers or the public would be (1) direct external exposure from radionuclides in the air and on the ground, (2) inhalation of radioactivity into the lungs after redistribution to other organs of the body, and (3) ingestion of radioactivity in foodstuffs for offsite members of the public.

Table D-3. Annual releases from normal operations.[a,b]

Radionuclide	Curies per year
Subsurface facility releases	
Activated air[c]	
Nitrogen-16	3.4×10^{-2}
Argon-41	2.0×10^{1}
Activated dust[c]	
Sodium-24	3.7×10^{-3}
Aluminum-28	1.6×10^{-3}
Silicon-31	5.2×10^{-4}
Potassium-42	8.0×10^{-4}
Iron-55	8.2×10^{-5}
Naturally occurring radioactivity[d]	
Radon-222	4.7×10^{3}
Surface facility releases	
Wet Handling Facility releases	
Hydrogen-3	5.8×10^{2}
Carbon-14	8.2×10^{-1}
Chlorine-36	1.7×10^{-2}
Krypton-85	6.4×10^{3}
Iodine-129	5.2×10^{-2}
Cesium-134	6.9×10^{-4}
Cesium-137	9.0×10^{-3}
Wet Handling Facility releases (continued)	
Barium-137m	8.5×10^{-3}
Crud (cobalt-60)	1.6×10^{-2}
Crud (iron-55)	2.0×10^{-1}
Fuel (cobalt-60)	4.1×10^{-5}
Nickel-63	5.0×10^{-6}
Strontium-90	8.6×10^{-4}
Yttrium-90	8.6×10^{-4}
Promethium-147	1.2×10^{-4}
Samarium-151	4.9×10^{-6}
Europium-154	5.7×10^{-5}
Europium-155	1.2×10^{-5}
Plutonium-238	7.5×10^{-5}
Plutonium-239	3.3×10^{-6}
Neptunium-239	7.4×10^{-6}
Plutonium-240	6.9×10^{-6}
Americium-241	2.4×10^{-5}
Plutonium-241	1.1×10^{-3}
Americium-243	7.4×10^{-7}
Curium-243	4.7×10^{-3}
Curium-244	1.1×10^{-4}

a. The listed source term nuclides contribute more than 99.9% of the total dose to the maximally exposed offsite member of the public.

b. Based on Wet Handling Facility throughput of 300 MTHM per year and a decontamination factor of 10,000 for a two-stage high-efficiency particulate air filter system in the Wet Handling Facility.

c. Source: DIRS 172487-BSC 2005, Table 13.

d. Assumes a fully excavated repository; Source: DIRS 167021-BSC 2003, p. 37.

D.3 Affected Populations and Individuals

Radiological impacts are measured in terms of doses to individuals and to populations. A dose is a measure of the amount of energy that radiation deposits in the body. A number of terms describe radiation doses. This analysis examined two dose categories: individual dose and population dose. Individual dose is a measure of the maximum dose to an individual. Population dose is a measure of the dose to the population outside the repository boundary or a group of workers inside the repository boundary; it is the sum of the doses to the individuals in the population or group of workers.

This section describes the four analyzed population groups and the locations of the maximally exposed individuals in each group: (1) the general population within 80 kilometers (50 miles) of the proposed repository, (2) the noninvolved worker population at the Nevada Test Site, (3) the noninvolved worker population at the repository, and (4) the involved worker population at the repository.

Members of the public, involved workers, and noninvolved workers could be exposed to atmospheric releases of radionuclides from repository activities. In this analysis, noninvolved worker population doses from radon releases apply to involved and noninvolved workers.

D.3.1 PUBLIC

The location of the maximally exposed member of the public would be at the southeastern boundary of the analyzed land withdrawal area in the prevailing downwind direction (southeast and south-southeast) from the release points. DOE determined this to be the location of unrestricted public access that would receive the highest radiation exposure. The release points for radon and other subsurface facility releases include the South Portal and one to six exhaust ventilation shafts. Normal operations releases of manmade radionuclides would occur only from the Wet Handling Facility, near the North Portal. The analysis used 22 kilometers (14 miles) in the south-southeast direction as a representative distance to the exposed individual location for releases from the Wet Handling Facility and 21 kilometers (13 miles) in the southeast direction for releases from subsurface facilities.

Table D-4 lists the estimated average population for 2067 of about 117,000 within 80 kilometers (50 miles) of the proposed repository. The analysis based this number on projected changes in the region, which includes the towns of Amargosa Valley, Beatty, Pahrump, and Indian Springs, and the surrounding rural areas. The analysis used information from state and local sources (Chapter 3, Section 3.1.8). The table lists the population in the vicinity of Pahrump even though part of the population would be beyond the 80-kilometer region. The analysis calculated both annual population dose and cumulative dose for the Proposed Action duration of 105 years, which would consist of 5 years of construction, 50 years of operations, 50 years of monitoring, and 10 years of closure, which overlaps the final 10 years of the monitoring period.

Table D-4. Projected 2067 population distribution within 80 kilometers of repository site.

Direction	Distance (kilometers)										
	8	16	24	32	40	48	56	64	72	80	Totals
South	0	0	39	1,000	1,685	402	0	2	0	0	3,128
South-southwest	0	0	0	1,107	245	0	0	2	0	0	1,354
Southwest	0	0	0	0	0	0	347	16	0	0	363
West-southwest	0	0	0	0	0	0	0	0	60	0	60
West	0	0	0	1,492	31	0	0	0	0	0	1,523
West-northwest	0	0	123	2,468	0	0	0	0	0	12	2,603
Northwest	0	0	0	69	0	0	0	0	85	0	154
North-northwest	0	0	0	0	0	0	0	0	0	0	0
North	0	0	0	0	0	0	0	0	0	0	0
North-northeast	0	0	0	0	0	0	0	0	0	0	0
Northeast	0	0	0	0	0	0	0	0	0	0	0
East-northeast	0	0	0	0	0	0	0	0	0	0	0
East	0	0	0	0	0	0	0	0	0	0	0
East-southeast	0	0	0	0	0	0	0	0	4,034	0	4,034
Southeast	0	0	0	0	0	0	90	8	16	516	630
South-southeast	0	0	0	0	74	427	69	172	21,281	81,612	103,635
Totals	0	0	162	6,136	2,035	829	506	200	25,476	82,140	117,484

Note: Conversion factors are on the inside back cover of this Repository SEIS.

D.3.2 NONINVOLVED WORKERS

The analysis assumed noninvolved workers on the surface would be at the site 2,000 hours a year (8 hours a day, 5 days a week, 50 weeks a year). Noninvolved workers would be construction, managerial, technical, supervisory, and administrative personnel who would not be directly involved in subsurface excavation and waste operations activities. In this analysis, noninvolved workers included onsite construction workers during the first several years of repository operations when construction activities would continue in parallel with ongoing operations. All workers, regardless of work responsibility, would receive exposure to releases of radon-222 and its decay products from the subsurface facilities. The maximally exposed noninvolved worker location for releases of radon and its decay products would be about 100 meters (330 feet) northeast of the South Portal development area for all analyzed periods. DOE based the noninvolved worker population in the South Portal development area on the number of full-time equivalent worker years for subsurface workers. The number of noninvolved workers in the South Portal development area would be 15 percent of the subsurface workers. During the construction period and the development of the first two emplacement panels during initial operations, ventilation air from repository excavation activities would exhaust from the South Portal and result in the highest potential exposure to radon and radon decay products. Once waste package emplacement began in Panel 2, DOE would convert the South Portal to an air intake, which would stop releases of radon gas from that location. For releases from the Wet Handling Facility during normal operations, the maximally exposed noninvolved worker location would be in the surface geologic repository operations area and vicinity. For the period during operations when there would be surface and subsurface sources of radionuclides, the maximally exposed noninvolved worker location would be the South Portal development area because radon releases would contribute most of the total worker dose.

The analysis evaluated DOE workers at the Nevada Test Site as a potentially exposed noninvolved worker population. The analysis used the current Test Site population of 1,544 workers for dose calculations (DIRS 182717-Skougard 2007, all). The analysis assumed that all these workers would be at Mercury, Nevada, about 50 kilometers (30 miles) east-southeast of the proposed repository.

Figure D-2 shows the estimated numbers of workers (involved and noninvolved) as a function of time.

D.3.3 INVOLVED WORKERS

Involved workers would be craft and operations personnel who were directly involved in waste operations activities and subsurface development, which would include subsurface excavation; receipt, handling, packaging, aging, and emplacement of spent nuclear fuel and high-level radioactive waste; monitoring of the condition and performance of the waste packages; and closure. To assess radiological health impacts to involved workers, the analysis assumed they would receive 2,000 hours per year of occupational exposure at the repository. The method used to assess radiological doses to the maximally exposed involved workers and the worker population is described in Section D.4.2.

D.4 Radiological Doses

This section describes the potential radiological health impacts to workers and the general public from proposed repository activities. It includes descriptions of the calculations and results for estimation of impacts under normal conditions for the public and involved and noninvolved workers for each period of the project (construction, operations, monitoring, and closure). Radiological impacts to workers include those from naturally occurring and manmade radiation and from radioactive materials in the workplace. Radiological impacts to members of the public include those from potential exposure to airborne releases of naturally occurring radiation and manmade radionuclides.

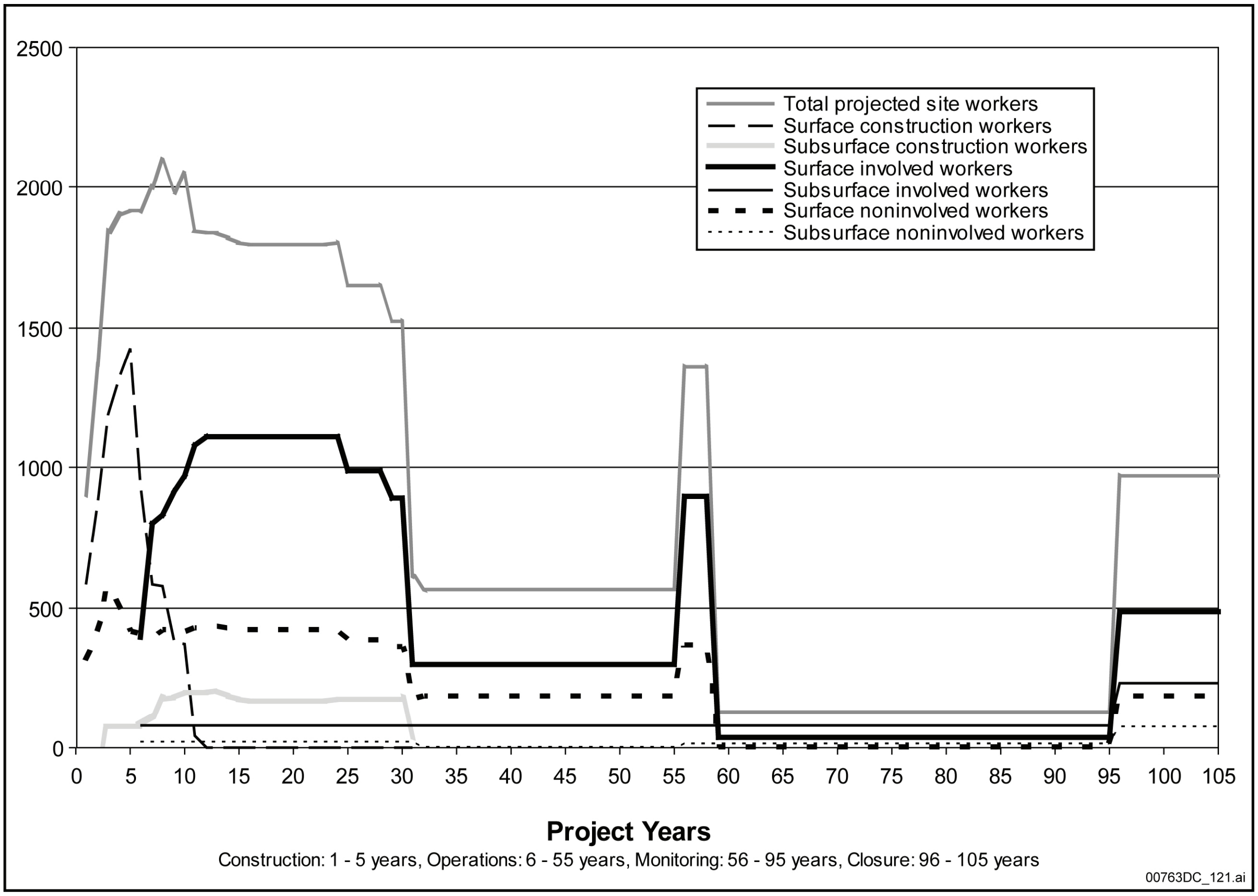

Figure D-2. Projected worker population for radiological impact assessment.

This section lists and describes radiological impacts to workers and the public as doses to the maximally exposed members of the worker and public populations and population doses for all workers and the affected public population within 80 kilometers (50 miles) of the repository.

D.4.1 ESTIMATED PUBLIC AND NONINVOLVED WORKER DOSES

D.4.1.1 Estimated Doses from Atmospheric Releases

The analysis used CAP88-PC, version 3 (DIRS 179923-Shroff 2006, all), a computer program that models atmospheric transport for assessment of dose and risk from radioactive air emissions, to calculate estimated population dose to the public and the dose to the maximally exposed workers and member of the public. CAP88-PC is the EPA-approved computer program for demonstration of compliance for emissions from DOE facilities [40 CFR 61.93(a)]. EPA has validated CAP88-PC by comparing its predictions of annual average concentrations to actual environmental measurements at five DOE sites (DIRS 179923-Shroff 2006, Section 1.4). The program provides capabilities for radon release dispersion and exposure calculations that include calculation of radon decay product concentrations in working levels. It uses dose factors in accordance with Federal Guidance Report 13 (DIRS 175452-EPA 1999, all). EPA based the Report 13 factors on the methods in Publication 72 of the International Commission on Radiological Protection (DIRS 172935-ICRP 2001, all).

CAP88-PC requires meteorological data in the form of the joint frequency distribution of wind speed, direction, and atmospheric stability class. The analysis compiled these data from onsite meteorological measurements at Yucca Mountain from 2001 to 2005 at Air Quality and Meteorology Monitoring Site 1 (DIRS 177510-BSC 2007, all and Attachment III). Site 1 is a 60-meter (197-foot) tower about 1 kilometer (0.6 mile) south-southwest of the North Portal. The measurement heights are 10 meters (33 feet) and 60 meters (197 feet).

The analysis used the CAP88-PC program with the meteorological data along with the source terms in Section D.2 to calculate the unit dose factors listed in Table D-5. These individual and population unit dose factors are normalized for the various sources. For surface facility release, the table lists the factors per MTHM of processed fuel. Factors for radon releases are per unit (1) curie of radon-222. Factors for other releases from the subsurface facilities are per year of operation. The analysis used the factors in Table D-5 to calculate doses from every year of repository operation and during each analyzed activity period.

Table D-5. Unit dose factors for maximally exposed individuals and total population dose for normal operations releases.

Source/facility	Maximally exposed individuals[a]				Population dose within 80 kilometers (person-rem)
	Offsite public (millirem)	Noninvolved subsurface worker (millirem)	Noninvolved surface worker (millirem)	NTS worker (millirem)	
Subsurface facility per curie radon release	0.0015	0.0011	0.00097	0.000031	0.033
South Portal per curie radon release[b]		0.066			
Surface facility per MTHM SNF processed	0.0000048	0.0000024	0.0000012	0.000000023	0.000097
Subsurface facility per year operation (non-radon release)	0.0011	0.0023	0.0048	0.000023	0.025

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. Based on maximum total individual dose over the entire project duration.

b. South Portal release applicable only to construction period.

NTS = Nevada Test Site.

MTHM = Metric tons of heavy metal.

SNF = Spent nuclear fuel.

The analysis calculated individual and population doses for every year of the analyzed project period from the beginning of construction to the end of closure. To estimate the maximum annual doses, the analysis assumed that the proposed repository would receive and process spent nuclear fuel and high-level radioactive waste at the design capacity. Multiplying the unit dose factors in Table D-5 by the projected annual spent fuel processing rate for the repository yielded the annual individual and population doses. The analysis calculated cumulative or time-integrated doses by summing the yearly doses.

Figure D-3 shows the annual individual and population doses to the public and the noninvolved workers as a function of time predicted for each year using the 105-year analysis period.

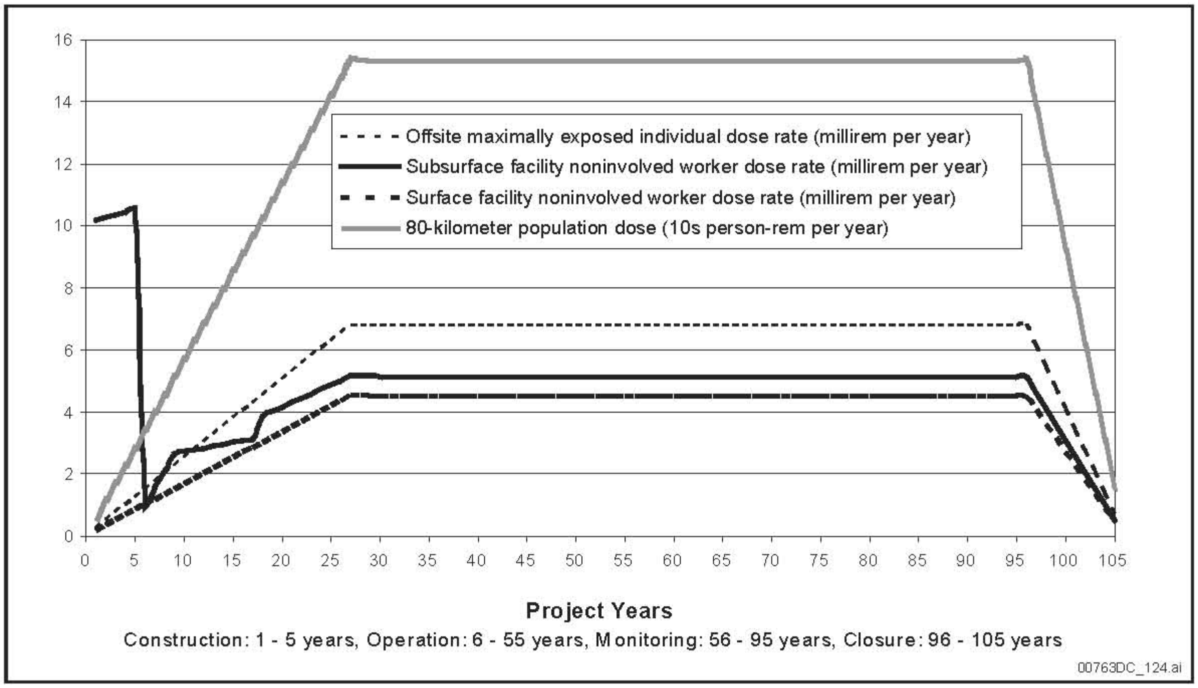

Figure D-3. Estimated individual and population doses from normal operations releases.

D.4.1.2 Estimated Doses to Workers from Direct Radiation

With the exception of subsurface involved workers, potential direct radiation exposures would originate only from surface facilities because massive layers of rock would shield workers from radiation sources such as waste packages inside subsurface facilities. Surface facilities with potential radiation sources that could contribute direct exposures to workers would include the transportation cask staging areas and the commercial spent nuclear fuel aging pads. All other surface facilities that handled radiological materials would provide concrete shielding for radiation sources, so dose rates at any potentially occupied areas would be negligible.

The analysis used dose rate versus distance information (DIRS 172729-BSC 2005, Table 4) and relative distances of the worker locations from the cask staging area to calculate dose rates at worker locations from exposure to external radiation from this source. It used dose rate-versus-distance information based on an aging overpack surface dose rate of 40 millirem per hour (DIRS 180131-BSC 2007, Figure 18) and relative distances of the worker locations from each aging pad to estimate dose rates at worker locations from exposure to commercial spent nuclear fuel on the aging pads.

The total estimated dose rate at a worker location would be the sum of all doses from casks temporarily at designated staging and aging areas. For conservatism, the analysis did not consider radiation shielding from construction materials and temporary shielding that DOE would provide for construction and operations activities. The calculated maximum annual dose and total dose for the entire operations period to a full-time noninvolved worker would be 7 millirem per year and 130 millirem, respectively. The total population dose to noninvolved workers over the entire operations period would be 63 person-rem. The analysis based the dose estimate over the operations period on the projection of annual commercial spent nuclear fuel processing rate and the capacity of the aging facility.

D.4.1.3 Estimated Total Public and Noninvolved Worker Doses from Normal Operations

Table D-6 summarizes estimates of radiation doses to members of the public and noninvolved workers for each analyzed activity period from normal operations.

Table D-6. Estimated radiation doses to the public and noninvolved workers for each analyzed activity period.[a]

Impact category	Construction	Operations	Monitoring	Closure
Maximum individual annual dose (millirem per year)				
Member of the public[b]	1.3	6.8	6.8	6.8
Noninvolved surface facility worker	0.83	11	4.5	4.5
Noninvolved subsurface facility worker	11	4.8	5.2	5.2
Maximum individual period total dose (millirem)				
Member of the public[b]	3.8	280	270	37
Noninvolved surface facility worker	2.5	320	180	25
Noninvolved subsurface facility worker	52	220	210	28
Population dose (person-rem)				
Exposed 80-kilometer population[c]	85	6,400	6,100	840
Noninvolved onsite population	4.7	230	26	18
Noninvolved Nevada Test Site population	0.12	9.2	8.9	1.2

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures.

a. About 99.9 percent of the dose and impact would be from naturally occurring radon-222 and its decay products.

b. At the southeastern boundary of the analyzed land withdrawal area.

c. The projected population would include about 117,000 individuals within 80 kilometers of the repository.

D.4.2 ESTIMATED INVOLVED WORKER DOSES

Involved worker radiation exposure at proposed repository facilities from normal operations could result from cask, fuel, and waste package handling; routine maintenance of the facilities; and airborne releases. In the subsurface repository, additional exposure could result from exposure to naturally occurring ambient radiation fields and elevated concentrations of radon-222 and its decay products.

The primary sources of radiation exposure to involved workers would be:

- Internal and external exposure of workers to naturally occurring radionuclides that would include:
  - Internal exposure by inhalation of radon-222 and its decay products in the air (subsurface workers could receive exposure from elevated concentrations of radon-222 and its decay products in the air in the repository drifts; workers on the surface could receive exposure to radon-222 releases from the subsurface ventilation exhausts), and
  - Direct external exposure of workers in the repository drifts as a result of naturally occurring radionuclides in the rocks of the drift walls (primarily potassium-40 and radionuclides of the naturally occurring uranium and thorium decay series);
- Internal and external exposure of workers to potential releases to air of radionuclides during handling of spent nuclear fuel in the repository; and

- External exposure of workers to direct radiation from contained sources, such as transportation casks, aging overpacks, and loaded waste packages during handling and packaging at the surface facilities and after emplacement in the subsurface facilities.

D.4.2.1 Estimated Doses from Naturally Occurring Radionuclides

D.4.2.1.1 *Ambient External Radiation*

Workers in the subsurface facility could receive exposure to external radiation from naturally occurring radionuclides in the drift rock. The analysis used an average ambient external radiation dose rate of 50 millirem per year (Chapter 3, Section 3.1.8) for a worker underground exposure time of 2,000 hours per year to calculate worker doses from ambient external radiation in the subsurface repository.

D.4.2.1.2 *Inhalation of Radon-222 and its Decay Products*

The analysis used predicted radon and decay product concentrations for the subsurface repository (DIRS 167021-BSC 2003, Table 5) to estimate potential dose rates for a subsurface worker from inhalation of radon-222 and its decay products. The predicted average concentrations in potentially occupied areas in the subsurface environment would be 5.8 picocuries per liter and 0.012 Working Level, respectively. The 0.012 Working-Level concentration converts to the worker exposure units of 0.14 Working-Level Months per year based on 2,000 hours per year of exposure. To convert Working-Level Months to rem, the analysis applied a conversion factor of 0.5 rem (500 millirem) per Working-Level Month for inhalation of radon decay products (DIRS 103279-ICRP 1994, p. 24).

Table D-7 lists estimated doses to involved workers for each analyzed activity period. The estimates include potential doses to the maximally exposed involved worker and the total dose for all involved workers from exposure to natural radiation sources.

Table D-7. Estimated radiation doses to involved workers from natural sources for each analyzed period.[a]

Impact category	Construction	Operations	Monitoring	Closure
Maximum individual annual dose (millirem per year)				
Surface facility	0.83	4.5	4.5	4.5
Subsurface facility	120	120	120	120
Maximum individual period total dose (millirem)				
Surface facility	2.5	190	180	25
Subsurface facility	490	6,100	4,900	1,200
Population dose (person-rem)				
Total worker population	33	910	390	320

Note: Numbers are rounded to two significant figures.
a. Doses from exposure to radon and ambient radiation.

D.4.2.2 Estimated Doses from Airborne Releases

The analysis used the calculated annual average atmospheric dispersion factors (DIRS 180308-BSC 2007, Table 7), the predicted quantity of radionuclide releases (Table D-3), and the projected spent nuclear fuel processing rate at the proposed repository to estimate annual doses to repository workers from potential Wet Handling Facility normal operational releases. The annual average dispersion factors represent the average dilution of airborne contamination from atmospheric mixing and turbulence; the analysis used the site-specific atmospheric conditions and the relative distance and configuration of the release point and the receptor of interest to calculate the dispersion factors.

Involved worker doses from airborne releases would include releases of manmade radionuclides through the subsurface ventilation exhaust. These releases could occur as a result of neutron activation of the air and dust. They would be the only airborne releases of manmade radionuclides during the monitoring and closure periods because the Wet Handling Facility would no longer be operating.

Table D-8 lists estimated radiological doses to involved workers from potential normal operational releases for each analyzed activity period. The estimated doses include potential doses to the maximally exposed involved worker and the total for all workers.

Table D-8. Estimated radiation doses to involved workers from manmade radionuclide releases during each project activity period.[a,b]

Impact category	Operations	Monitoring	Closure
Maximum individual annual dose (millirem per year)			
Surface facility	0.35	0.0048	0.0048
Subsurface facility	0.054	0.047	0.047
Maximum individual period total dose (millirem)			
Surface facility	7.4	0.19	0.026
Subsurface facility	2.5	1.9	0.26
Total worker population dose (person-rem)	1.8	0.17	0.13

Note: Numbers are rounded to two significant figures.

a. Doses incurred from exposure to both surface and subsurface normal operations releases.

b. There would be no manmade radionuclide releases during the construction period.

D.4.2.3 Estimated Doses from Direct Radiation

The analysis assessed annual doses to repository workers from exposure to direct radiation emitted from contained sources, such as transportation casks and waste packages, during normal operations for each of the following repository facilities:

- Receipt Facility,
- Initial Handling Facility,
- Wet Handling Facility,
- Canister Receipt and Closure Facilities,
- Subsurface facility,
- Aging pads, and
- Low-Level Waste Facility.

With the exception of the Low-Level Waste Facility, dose assessments derive from the current facility general arrangement and projections of annual transportation cask, TAD canister, and waste package processing rates with the current simulated throughput model. The Low-Level Waste Facility would collect, package, and ship low-level radioactive waste to an approved disposal facility.

The analysis based dose assessments by worker group on job function and used time-motion inputs and calculated dose rates at worker locations. For cask processing facilities, the analysis based dose rates estimated for the design-basis commercial spent nuclear fuel. The assessments considered all major activities, the types and numbers of involved workers in each activity, the duration of exposure, and the dose rate during that exposure period for each worker. The analysis calculated doses for a unit campaign—that is, for a typical received transportation cask and a delivered TAD canister or waste package. The estimated annual doses to the facility workers are the product of the unit campaign doses and the projected bounding number of campaigns during a year.

The calculated doses include the contributions from direct external radiation and airborne radionuclides. Calculation results indicate that the inhalation and submersion doses would represent a small fraction of the total worker doses. The analysis calculated total worker population doses from the total number of cask and waste package campaigns over the entire operations period. Table D-9 lists the estimated surface worker doses during the operations period. There would be no direct external radiation exposure to surface workers during the construction, monitoring, and closure periods. Table D-10 summarizes the estimated subsurface worker doses during the operations, monitoring, and closure periods. The estimated doses in Tables D-9 and D-10 include potential doses to the maximally exposed involved worker for each repository facility and the population total for all involved workers. The total estimated worker population doses for all surface and subsurface activities during the operations period would be 4,300 person-rem and 510 person-rem, respectively. The largest contributions to individual and population doses would be preparation of casks and the transferal of casks to waste processing and storage areas in surface facilities.

Table D-9. Estimated radiation doses to involved surface workers from manmade external radiation during operations period.

Facility	Impact category[a,b]	Dose
Receipt Facility	Maximum annual individual dose (rem/year)	1.3
	Total individual dose (rem)	30
	Total population dose (person-rem)	850
Initial Handling Facility	Maximum annual individual dose (rem/year)	0.81
	Total individual dose (rem)	19
	Total population dose (person-rem)	110
Wet Handling Facility	Maximum annual individual dose (rem/year)	0.96
	Total individual dose (rem)	22
	Total population dose (person-rem)	810
Canister Receipt and Closure Facilities	Maximum annual individual dose (rem/year)	0.29
	Total individual dose (rem)	6.8
	Total population dose (person-rem)	580
Aging pads	Maximum annual individual dose (rem/year)	0.89
	Total individual dose (rem)	21
	Total population dose (person-rem)	1,600
Low-Level Waste Facility	Maximum annual individual dose (rem/year)	0.95
	Total individual dose (rem)	22
	Total population dose (person-rem)	370
Total surface repository operations	Population dose (person-rem)	4,300

Source: (DIRS 182604-Darling 2007, Attachment I).
Note: Numbers are rounded to two significant figures.
a. Annual doses based on process of 3,000 MTHM commercial spent nuclear fuel throughput per year or about 500 casks per year.
b. Total doses based on process of a total waste throughput of 70,000 MTHM.
MTHM = Metric tons of heavy metal.

These conservative estimates of involved worker doses do not take credit for the application of administrative limits to reduce individual exposures. The Department would apply additional measures to ensure that radiation exposures to workers were as low as reasonably achievable.

Table D-10. Estimated radiation doses to involved subsurface workers from manmade external radiation during each project activity period.[a,b]

Impact category	Operations	Monitoring	Closure[c]
Maximum annual individual dose (millirem per year)	210	200	39
Total individual dose (rem)	10	8	0.39
Total population dose (person-rem)	510	510	80

Source: DIRS 182715-BSC 2007, Sections 6.2 and 6.3.
Note: Numbers are rounded to two significant figures.
a. Doses incurred from loaded waste packages inside the subsurface drifts.
b. There would be no manmade external radiation sources during the construction period.
c. Doses incurred from backfill operations.

D.4.3 ESTIMATED TOTAL RADIOLOGICAL DOSES FOR ENTIRE PROJECT

This section summarizes the total radiological doses to workers and members of the public from activities at the proposed Yucca Mountain repository. The entire project would last 105 years and include a 5-year construction period, 50-year operations period, 50-year monitoring period, and 10-year closure period, which would overlap the last 10 years of the monitoring period.

Table D-11 summarizes estimates of radiological doses to the public for each activity period and for the entire project duration. It lists estimated radiation doses for the maximally exposed member of the public and the potentially exposed population. About 99.9 percent of the potential doses would be from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air. Estimated individual doses would be for the offsite maximally exposed member of the public who resided continuously for 70 years at the site boundary location in the prevailing downwind direction. The highest annual radiation dose would be 6.8 millirem, which is less than 4 percent of the annual average 200- millirem dose to members of the public from ambient levels of naturally occurring radon-222 and its decay products (Chapter 3, Section 3.1.8.2). The estimated collective dose for the population within 80 kilometers (50 miles) for the entire project duration of 105 years would be 13,000 person-rem. This population dose can be compared with about 2.5 million person-rem in the projected population in 2067 of about 117,000 persons within 80 kilometers of the repository would receive from natural background radon exposure.

Table D-11. Estimated radiation doses to the public during each activity period and entire project duration.[a]

Impact category	Construction	Operations	Monitoring[b]	Closure	Entire project
Maximally exposed member of the public[c]					
Maximum annual dose (millirem per year)	1.3	6.8	6.8	6.8	6.8
Total dose (millirem)	3.8	280	270	37	480[d]
Population[e] dose (person-rem)	85	6,400	6,100	840	13,000

Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.
a. About 99.9 percent of the dose and impact would be from naturally occurring radon-222 and its decay products.
b. Doses are for monitoring period under active ventilation operating mode.
c. At the southeastern boundary of the analyzed land withdrawal area.
d. Based on a 70-year exposure of the maximally exposed individual.
e. The projected population includes about 117,000 individuals within 80 kilometers of the repository.

Table D-12 lists estimates of radiological doses to workers for each repository activity period and for the entire project. The estimated radiological doses include potential doses to involved workers, noninvolved workers, and the total for all workers. The table lists estimated doses for the maximally exposed involved

Table D-12. Estimated radiation doses to workers during each activity period and entire project duration.

Worker group and impact category	Construction[a]	Operations	Monitoring[b]	Closure	Entire project
Maximum individual annual dose (rem per year)					
Surface facility involved worker	0.00083	1.3	0.0045	0.0045	1.3
Subsurface facility involved worker	0.12	0.33	0.33	0.16	0.33
Onsite noninvolved worker	0.011	0.011	0.0052	0.0052	0.011
NTS noninvolved	0.000026	0.00014	0.00014	0.00014	0.00014
Maximum individual period total dose (rem)					
Surface facility involved worker	0.0025	30	0.18	0.025	30
Subsurface facility involved worker	0.49	17	13	1.6	17
Onsite noninvolved worker	0.052	0.32	0.21	0.028	0.32
NTS noninvolved	0.000079	0.0059	0.0057	0.00078	0.0059
Population dose (person-rem)					
Surface facility involved worker	--	4,300	0.019	0.023	4,300
Subsurface facility involved worker	33	1,400	890	400	2,700
Onsite noninvolved worker	4.7	230	26	18	280
NTS noninvolved	0.12	9.2	8.9	1.2	19
Total worker population	38	6,000	930	420	7,400

Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.
a. Only subsurface workers have potential for measurable radiation dose from natural sources.
b. Doses are for monitoring period under active ventilation operating mode.
NTS = Nevada Test Site.

worker and for the involved worker population; doses for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated population doses for the combined population of workers. The estimated total worker population radiation dose for the entire project duration of 105 years would be 7,400 person-rem. About 80 percent of the dose would occur during the operations period for the repository workforce. The principal source of exposure would be external radiation from handling of spent nuclear fuel in surface facilities and monitoring and maintenance activities in the subsurface facility. Exposure to the naturally occurring radioactive sources would account for 22 percent of the total worker dose. Inhalation of radon-222 and its decay products by subsurface workers would contribute 13 percent of the total dose, and ambient radiation exposure to subsurface workers would contribute 9 percent. To put the 7,400-worker person-rem occupational risk in perspective, the estimated worker population year of about 86,000 number of full-time equivalent worker years would receive 29,000 person-rem from natural background radiation exposure of 340 millirem per year (Chapter 3, Section 3.1.8.1) over the entire project period of 105 years. Therefore, the addition of 7,400 person-rem would represent a 25-percent increment.

D.5 Preclosure Radiological Human Health Impacts

To calculate the potential impacts to human health from the estimated radiation doses, the analysis multiplied the doses from Tables D-11 and D-12 by the updated dose-to-health risk conversion factors (Section D.1.6). The estimated potential radiological health impacts cover the entire project duration of 105 years. This section discusses radiological health impacts for the maximally exposed workers and member of the public as increases in the probabilities of latent cancer fatality from the received radiation doses, and it provides health impacts for exposed populations as the estimated numbers of latent cancer fatalities that could occur with the exposed population. For this Repository SEIS, the analysis used the conversion factor of 0.0006 latent cancer fatality per person-rem to convert worker and public doses to health effects.

D.5.1 ESTIMATED HEALTH IMPACTS TO THE GENERAL POPULATION

Table D-13 summarizes estimates of radiological health impacts to the public for each activity period and the entire project duration. It lists estimated health effects for the offsite maximally exposed member of the public and the potentially exposed population. As indicated in Section D.4.3, almost all of the potential health impacts would be from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air.

Table D-13. Estimated radiological health impacts to the public for each repository activity period and entire project duration.[a]

Health impact	Construction	Operations	Monitoring[b]	Closure	Entire project
Maximally exposed member of the public[c]					
Increase in probability of latent cancer fatality	0.0000023	0.00017	0.00016	0.000022	0.00029
Exposed 80-kilometer population[d]					
Number of latent cancer fatalities	0.051	3.8	3.7	0.51	8

Notes: Conversion factors are on the inside back cover of this Repository SEIS. Numbers are rounded to two significant figures; therefore, totals might differ from sums.

a. About 99.9 percent of the dose and impact would be from naturally occurring radon-222 and decay products.
b. Doses are for monitoring period under active ventilation operating mode.
c. At the southeastern boundary of the land withdrawal area.
d. The projected population includes about 117,000 individuals within 80 kilometers of the repository.

The estimated increase in probability of a latent cancer fatality to the maximally exposed hypothetical individual who resided continuously for 70 years at the site boundary location in the prevailing downwind direction during the preclosure period would be about 0.0003. The estimated number of latent cancer fatalities would be 8 in a projected population in 2067 of about 117,000 persons within 80 kilometers (50 miles) of the repository. For comparison, the analysis examined the number of expected cancer deaths that would occur from other causes in the same population during the same periods. The analysis calculated the expected number of cancer deaths that would not be related to the repository project on the basis of current statistics from the Centers for Disease Control and Prevention, which indicated that 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause during 1998 (DIRS 153066-Murphy 2000, p. 8). The comparison indicates that over the 105-year project duration the incremental chance of latent cancer fatalities among the projected population of about 117,000 would be about 2 in 10,000.

D.5.2 ESTIMATED HEALTH IMPACTS TO WORKERS

Table D-14 summarizes estimates of radiological health impacts to workers for each repository activity period and for the entire project duration. It lists estimated radiological health impacts for the maximally exposed involved worker and the involved worker population, the maximally exposed noninvolved worker and the noninvolved worker population, and the combined population of workers.

The estimated increase in number of latent cancer fatalities that could occur in the repository workforce from the received radiation doses over the entire project would be 4.4. This can be compared to the 17 latent cancer fatalities that the same worker population would normally incur over the entire project duration of 105 years from exposure to natural background radiation of 340 millirem per year (Chapter 3, Section 3.1.8.1).

Table D-14. Estimated radiological health impacts to workers for each repository activity period and entire project duration.

Health impact/ worker group	Construction	Operations	Monitoring[a]	Closure	Entire project
Increase in probability of latent cancer fatality for the maximally exposed worker					
Involved	0.00029	0.018	0.0078	0.0010	0.018
Noninvolved	0.000031	0.00019	0.00012	0.000017	0.00019
Number of latent cancer fatalities in worker population					
Involved	0.02	3.5	0.54	0.24	4.2
Noninvolved	0.0028	0.14	0.016	0.011	0.17
Nevada Test Site noninvolved	0.000074	0.0055	0.0053	0.00073	0.012
Total	0.023	3.6	0.56	0.25	4.4

Note: Numbers are rounded to two significant figures; therefore, totals might differ from sums.
a. Health effects are for monitoring period under active ventilation operating mode.

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Appendix E

Potential Repository Accident Scenarios and Sabotage: Analytical Methods and Results

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E. POTENTIAL REPOSITORY ACCIDENT SCENARIOS AND SABOTAGE: ANALYTICAL METHODS AND RESULTS

This appendix describes the methods and detailed results of the analysis the U.S. Department of Energy (DOE or the Department) performed for this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) to assess the potential impacts from hypothetical accident and sabotage scenarios at the repository. The scenarios and methods apply only to repository accidents that could occur during operations, monitoring, and closure. This appendix describes the details of calculation methods for specific scenarios that the analysis determined to be credible. Appendix G describes the analytical methods and results for estimation of impacts from accidents that could occur during loading activities at the 72 commercial and 4 DOE sites and during transportation of materials to the repository.

DOE based the accident scenarios in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, all) (Yucca Mountain FEIS), on the information available at the time about the repository design. The analysis of the impacts relied on assumptions and analyses DOE selected to ensure that it did not underestimate the impacts from accident scenarios. Since the completion of the Yucca Mountain FEIS, the Department has modified the design and operating philosophy for the repository. DOE would now use phased construction of multiple surface facilities, and most of the commercial spent nuclear fuel would arrive in transport, aging, and disposal (TAD) canisters. DOE has reevaluated the potential for repository accidents for this Repository SEIS. In addition, the Department has identified accident scenarios based on the current design and operating philosophy (1) to evaluate their impacts to support the application for construction authorization and (2) to assess whether the repository would comply with regulatory limits on radiation exposure to workers and the public from accidental releases of radionuclides. To meet licensing requirements, the results from the accident analysis will be more specific and comprehensive than those in this appendix and they will reflect a more fully developed repository design and operational details. To be consistent with the current design and operating philosophy, DOE revised the Yucca Mountain FEIS accident analyses, which now reflect the data and accident modeling changes.

Section E.1 describes the general methodology for the accident analysis and Section E.2 describes the selection of accident scenarios for analysis. Sections E.3 and E.4 discuss source terms and consequences for the analyzed accident scenarios, respectively. Sections E.5 and E.6 discuss accidents in relation to monitoring and closure, and Inventory Modules 1 and 2, respectively. Section E.7 discusses the scenario DOE chose to represent a potential sabotage event.

E.1 General Methodology

This analysis incorporates, as appropriate, accident analyses DOE has prepared since completion of the FEIS to account for the current design and revised data and changes in analytical methods for consequence analyses. Section E.7 describes the scenario DOE chose to represent a hypothetical sabotage event and the potential consequences of that scenario.

Because of the large amount of radioactive material workers would handle at the proposed repository (Chapter 2, Section 2.1), the focus of the analysis was on accident scenarios that could cause the release of radioactive material to the environment. DOE analyzed selected accident scenarios to determine the amount of radioactive material an accident could release to the environment and to estimate the consequences of the release in terms of health effects to workers and the public. The accident scenarios DOE selected include a spectrum of both high-frequency, low-consequence accident scenarios and low-frequency, high-consequence accident scenarios in accordance with DOE *National Environmental Policy Act* (NEPA; 42 U.S.C. 4321 et seq.) guidance (DIRS 178579-DOE 2004, p. 27).

The analysis derived accident frequency estimates to establish the credibility of an accident scenario (that is, to determine whether an accident scenario is reasonable foreseeable). For these accident scenarios that DOE determined to be reasonably foreseeable, DOE estimated the potential consequences, which are presented without discounting for accident frequency (in other words, DOE did not multiply the consequences by the estimated frequencies to derive point estimates of risks). Estimates of accident frequency are inherently uncertain. Based on the available design information, DOE used the accident analysis approach this appendix describes to ensure it would not underestimate potential accident impacts.

For accidents that do not involve radioactive materials, the analysis determined that application of accident statistics from other DOE operations would provide a reasonable estimate of nonradiological accident impacts (Section E.2.2).

E.2 Potential Operations Accident Scenarios

The analysis identified potential repository accident scenarios for preclosure operations by using scenarios DOE has developed for the current design in *Yucca Mountain Project Critical Decision-1, Preliminary Hazards Analysis* (DIRS 176678-DOE 2006, all). Section E.2.1 describes the radiological accident scenarios, all of which would apply during operations activities. Section E.2.2 discusses the treatment of nonradiological accidents.

E.2.1 RADIOLOGICAL ACCIDENT SCENARIOS

Radiological accidents involve an initiating event that could lead to a release of radioactive material to the environment. The analysis considered accident scenarios separately for two types of initiating events: (1) internal initiating events that would originate in the repository and involve equipment failure, human error, or both, and (2) external initiating events that would originate outside the facility and affect the ability of the facility to maintain confinement of radioactive or hazardous material.

E.2.1.1 Internally Initiated Events

As noted, the *Yucca Mountain Project Critical Decision-1 Preliminary Hazards Analysis* (DIRS 176678-DOE 2006, all) provides the most recent repository accident scenario analysis for internal and external events that involved receipt, handling, or emplacement of spent nuclear fuel and high-level radioactive waste. That document addressed U.S. Nuclear Regulatory Commission (NRC) requirements in 10 CFR 63.112 and preclosure performance objectives in 10 CFR 63.111. The analysis was a comprehensive evaluation of repository operations to identify accident sequences that could lead to a radioactive release. DOE performed detailed analyses on the sequences using event trees and fault trees to estimate accident frequencies. As required by 10 CFR Part 63, the analysis used the frequency evaluation to identify (1) Category 1 events (sequences that would be likely to occur one or more times before permanent closure), (2) Category 2 events (sequences that would have at least a 1-in-10,000 chance of occurring before permanent closure), or (3) beyond-design-basis Category 2 events (which would have a frequency of less than 1 in 1 million before permanent closure). The period before permanent closure includes a period up to 50 years for receipt, handling, or emplacement operations (DIRS 176678-DOE 2006, p. 4-6). For Category 1 events that could happen only during these operations, the average annual probability threshold would be approximately 1 in 50, or 0.02 per year. The total period of activity before permanent closure would be 100 years, so the average annual probability threshold for events that could occur anytime before permanent closure would be 0.01 per year. Similarly, the Category 2 event threshold is 2×10^{-6} per year (1 in 10,000 divided by 50) for events that could occur only during receipt, handling, or emplacement operations. The event categorization analysis identified a number of beyond-Category-2 events that DOE eliminated from further consideration (DIRS 176678-DOE 2006, Section 4.4.5 and Appendix A). However, DOE NEPA guidance recommends consideration of these events for evaluation if (1) they have an annual frequency above 1×10^{-7} per year, and (2) the consequences could be very large (DIRS 178579-DOE 2004, p. 28). As discussed in Section E.2.1.1.8, none of these beyond-Category 2 event sequences have the potential to produce consequences greater than the aircraft crash evaluated as a sabotage event in Section E.7 and, therefore, DOE did not evaluate them further in this Repository SEIS.

The evaluation that identified the internal accident scenarios (DIRS 176678-DOE 2006, all) did not quantitatively evaluate criticality events. DOE will address the means to prevent and control criticality as part of the Yucca Mountain preclosure safety analysis required for compliance with 10 CFR Part 63, in which the preclosure period covers the time before and during, permanent closure activities. The criticality objective of the preclosure safety analysis as stated in 10 CFR 63 is to perform:

> "…an analysis of the performance of the structures, systems, and components to identify those that are important to safety. This analysis identifies and describes the controls that are relied on to limit or prevent potential event sequences or mitigate their consequences. This analysis also identifies measures taken to ensure the availability of safety systems. The analysis required in this paragraph must include, but not necessarily be limited to, consideration of…(6) Means to prevent and control criticality…" [10 CFR Part 63, Subpart E, Section 112(e)].

To comply with this requirement, DOE has developed a process that it would use to demonstrate subcriticality for all preclosure operations with fissile materials for normal operations and for Category 1 and Category 2 event sequences. Subcriticality is defined as an end-state configuration with a maximum k_{eff} of less than an upper subcritical limit, which includes allowance for calculational bias and for administrative margin. Maintaining k_{eff} less than an upper subcritical limit prevents the occurrence of criticality. A demonstration of subcriticality is based on passive engineered systems (for example, fixed and soluble neutron absorbers, moderator control) with minimal reliance on administrative controls or operator intervention.

Even though it will be quantitatively demonstrated that no event sequence with a mean probability of occurrence greater than 1×10^{-4} during the preclosure period would result in a configuration that violated the upper subcritical limit, the actual likelihood of a criticality accident is significantly lower given the following conservatisms in the analysis:

- Commercial spent nuclear fuel represented as fresh (that is, no burnup credit), with an enrichment of 5 weight-percent uranium-235. This is conservative because the commercial spent nuclear fuel received at the repository will have a range of enrichments below 5 weight-percent uranium-235 and reduced fissionable material compared to fresh fuel due to burnup in a commercial reactor.

- Evaluation of the most reactive fuel state for DOE spent nuclear fuel (that is, fresh fuel for non-breeder reactor fuel, or calculated most reactive state for breeder reactor fuel). This is conservative because evaluation of the most reactive fuel state puts an upper bound on the potential for criticality.

- No credit for the presence of uranium-234 and -236. These isotopes are neutron absorbers that reduce the potential for criticality.

- Credit for only 75 percent of the neutron absorber loading. This assumption reduces the neutron absorber effect and thus increases the availability of neutrons that can cause fission.

- No credit for fixed neutron absorbers in moderator control facilities. This assumption also reduces the neutron absorber effect and thus increases the availability of neutrons that can cause fission.

- An administrative margin between the criterion to determine subcriticality and the actual critical calculated state.

Criticality could occur if the commercial spent nuclear fuel was moderated with water and had sufficient fissionable material in a configuration to allow criticality. However, the only place that DOE would store spent nuclear fuel in water would be the Wet Handling Facility storage pool. The water in this pool would be borated to prevent criticality. For DOE spent nuclear fuel that could be self-moderated (for example, spent nuclear fuel from training, research, isotopes General Atomics reactors or fast reactor fuel), DOE would use robust canisters, fixed neutron absorbers, and basket designs that provided fuel geometry controls to control criticality.

Considering these factors, DOE has determined that criticality would not be a credible event.

Table E-1 lists the accident scenarios that internal events could initiate that DOE included in the analysis. The table lists the Category 2 accident scenarios (DIRS 176678-DOE 2006, Section 4.4.4). The analysis did not identify any Category 1 scenarios. In addition, DOE performed a qualitative evaluation of beyond-Category-2 accident scenarios (Section E.2.1.1.8).

The Scenario Number column in Table E-1 provides a numerical identifier. The Location column lists the repository location designator where the accident scenario could occur. The Description column describes the scenario. The Material at Risk column identifies the radioactive material the scenario would involve. The final column lists the estimated annual frequency for the scenario.

The waste forms that DOE would receive at the repository include commercial and DOE spent nuclear fuel and high-level radioactive waste. None of the event sequences in Table E-1 involves DOE spent nuclear fuel other than naval spent nuclear fuel. This is because the Department intends to implement a safety strategy that would preclude a breach during handling of DOE spent nuclear fuel canisters other than naval spent nuclear fuel (DIRS 176678-DOE 2006, p. A-1).

DOE selected fuel from pressurized-water reactors for accident scenarios that could involve commercial spent nuclear fuel because it would be the most common type of fuel in the proposed repository (DIRS

Table E-1. Evaluated accident scenarios with internal initiators.

Scenario number	Location	Description	Material at risk	Expected occurrences over preclosure period (annual frequency)[a]
1	Initial Handling Facility, Canister Receipt and Closure Facilities	Breach of naval canister	1 naval canister	1.7×10^{-2} (3.4×10^{-4})
2	Initial Handling Facility, Canister Receipt and Closure Facility	Drop and breach of HLW canister in transportation cask	5 HLW canisters	2.1×10^{-2} (4.2×10^{-4})
3	Initial Handling Facility, Canister Receipt and Closure Facility	Breach of HLW canister in unsealed waste package or drop of equipment on HLW causing breach while in transportation cask or waste package	5 HLW canisters	9.8×10^{-2} (2.0×10^{-3})
4	Initial Handling Facility, Canister Receipt and Closure Facility	Drop with breach of HLW canister during transfer	2 HLW canisters	2.1×10^{-1} (4.2×10^{-3})
5	Wet Handling Facility	Drop of truck transportation cask without impact limiters causing breach	4 PWR or 9 BWR fuel assemblies	8.7×10^{-2} (1.7×10^{-3})
6	Wet Handling Facility	Drop of inner lid of truck transportation cask onto fuel assemblies in cask under water	4 PWR or 9 BWR fuel assemblies	4.4×10^{-2} (8.8×10^{-4})
7	Receipt Facility, Wet Handling Facility	Breach of DPC from drop or equipment impact	36 PWR or 74 BWR fuel assemblies	5.7×10^{-2} (1.1×10^{-3})
8	Wet Handling Facility	Breach of DPC under water from drop or equipment impact	36 PWR or 74 BWR fuel assemblies	2.1×10^{-2} (4.2×10^{-4})
9	Receipt Facility, Wet Handling Facility, Canister Receipt and Closure Facility	Drop and breach of TAD canister during handling operations	21 PWR or 44 BWR fuel assemblies	5.0×10^{-1} (1.0×10^{-2})
10	Wet Handling Facility	Drop of TAD canister lid onto fuel assemblies under water	21 PWR or 44 BWR fuel assemblies	1.7×10^{-2} (3.3×10^{-4})
11	Wet Handling Facility	Drop of one fuel assembly on another with breach under water	2 PWR or 2 BWR fuel assemblies	4.8×10^{-1} (9.6×10^{-3})
12	Wet Handling Facility	Drop of equipment on fuel assembly with breach under water	1 PWR or 1 BWR fuel assemblies	4.8×10^{-1} (9.6×10^{-3})
13	Low-Level Waste Facility	Fire involving low-level radioactive waste	Filters, spent resin, dry active waste, liquid waste	5.0×10^{-1} (1.0×10^{-2})

a. Annual frequency is estimated by dividing the expected number of occurrences over the preclosure period by the preclosure operating interval of 50 years.

BWR = Boiling-water reactor.
DPC = Dual-purpose canister.
HLW = High-level radioactive waste.
PWR = Pressurized-water reactor.
TAD = Transportation, aging, and disposal (canister).

155970-DOE 2002, Appendix A, p. A-15) and because it would produce higher doses than boiling-water reactor fuel for equivalent accident scenarios (Section E.3.3).

E.2.1.1.1 *Initial Handling Facility*

The Initial Handling Facility would receive high-level radioactive waste and naval spent nuclear fuel in canisters and transfer them from transportation casks into waste packages. The Initial Handling Facility would receive, package, and support placement of waste. Waste transfer operations would occur inside concrete enclosures.

The Initial Handling Facility would interface with the other facilities as follows:

- Receive casks with high-level radioactive waste and naval spent nuclear fuel on transporters from the rail or truck receiving yard,
- Receive empty waste packages, lids, and shield plugs from the warehouse for the processing of the canisters, and
- Receive support equipment for each waste package.

The preliminary hazards analysis report (DIRS 176678-DOE 2006, all) did not consider accidents in the Initial Handling Facility because the facility was not yet part of the design. However, the Initial Handling Facility operations would be similar to the handling of high-level radioactive waste in the Canister Receipt and Closure Facility. Therefore, DOE assumes the same accident scenarios would apply. Because the number of canisters would remain the same, the number of handling operations would also be the same. Therefore, the accident frequencies in Table E-1 would be valid for the two facilities. DOE identified Scenarios 2 to 4 involving high-level radioactive waste (Table E-1) for the Canister Receipt and Closure Facility. These accident scenarios would apply to the Initial Handling Facility.

E.2.1.1.2 *Receipt Facility*

The functions of the Receipt Facility would be to (1) receive loaded transportation casks, (2) remove personnel barriers and impact limiters from the casks, and (3) transfer the TAD or dual-purpose canister from the transportation cask to a shielded transfer cask for movement to the Wet Handling Facility, one of the Canister Receipt and Closure Facilities, or an aging pad after placement in an aging overpack. Because the Canister Receipt and Closure Facilities would also directly receive TAD canisters in transportation casks, the primary function of the Receipt Facility would be to transfer TAD canisters and dual-purpose canisters from transportation casks to aging overpacks. In addition, the Receipt Facility would transfer TAD canisters from shielded transfer casks to aging overpacks, and transfer dual-purpose canisters from aging overpacks to shielded transfer casks, for movement to and from the Wet Handling Facility.

The Receipt Facility would receive only rail carriers directly. No uncanistered spent nuclear fuel would be handled in the Receipt Facility, and no canisters would be opened inside. There would be direct rail access to the Receipt Facility with a trench in the operating floor to position the deck of the railcar even with the operating floor.

The facility would consist of a multipurpose cell for shielded handling of TAD and dual-purpose canisters, as well as the aging overpacks and shielded transfer casks that held the canisters. The facility would accommodate the cask transporter for movement of the loaded aging overpacks and transfer casks to aging pads and to a Canister Receipt and Closure Facility, respectively. The cask transporter would move dual-purpose canisters in shielded transfer casks to the Wet Handling Facility and vertical dual-purpose canisters in aging overpacks to an aging pad. Casks containing horizontal dual-purpose canisters would be moved to the aging pad via a transfer trailer where the horizontal dual-purpose canister would be pushed into the aging overpack.

The receipt of TAD and most dual-purpose canisters and the transfer of these canisters to shielded transfer casks and aging overpacks would utilize the vertical transfer method in *Yucca Mountain Project Critical Decision-1 Preliminary Hazards Analysis* (DIRS 176678-DOE 2006, p. 3-18, and Section 3.2.2.6.1.). Casks containing horizontal dual-purpose canisters would be transferred to the aging pad where the dual-purpose canister was pushed into the aging overpack. In this case, the dual-purpose canisters would be handled via a horizontal transfer method.

The Receipt Facility would have a filtered exhaust system with high-efficiency particulate air filters to mitigate the consequences of a radioactive release from a canister drop.

In evaluating the potential hazards of operations in the Receipt Facility, DOE identified two general accident scenarios with the potential to release radioactive material (DIRS 176678-DOE 2006, Table 4-5): Scenario 7, breach of a dual-purpose canister from drop or equipment impact, and Scenario 9, drop and breach of a TAD canister. These scenarios represent accidents that could occur during operations at the Receipt Facility that involved moving or lifting the dual-purpose and TAD canisters or that involved handling equipment over a dual-purpose canister when the canister was vulnerable to an equipment drop or fall. The estimated frequency of this accident takes into account the number of dual-purpose and TAD canisters the facility would handle and the number of operations for each canister. The analysis retained these scenarios for calculation of consequences.

E.2.1.1.3 *Aging Pads*

DOE would place TAD canisters into aging overpacks at the Wet Handling Facility, the Receipt Facility, and the Canister Receipt and Closure Facility. The aging overpacks would then be transferred to the aging pads to age the waste until it was ready for emplacement or repackaging. Vertical dual-purpose canisters could be placed into aging overpacks at the Receipt Facility and Canister Receipt and Closure Facility and also transferred to the aging pads. Casks containing horizontal dual-purpose canisters could be placed on a transfer trailer and moved to the aging pad where the dual-purpose canisters were pushed into an aging overpack. There would be two aging pads with 2,500 spaces for storage of up to 21,000 metric tons of heavy metal of waste. Chapter 2 provides a detailed description of aging operations. In evaluating these operations, DOE did not identify any Category 2 accident scenarios resulting in a release of radioactive materials.

E.2.1.1.4 *Wet Handling Facility*

The Wet Handling Facility would:

- Receive transportation casks from truck or rail buffer areas with commercial spent nuclear fuel assemblies. The Wet Handling Facility would handle commercial spent nuclear fuel in dual-purpose canisters and transportation casks.

- Receive empty TAD canisters from the Warehouse and Non-Nuclear Receipt Facility for transfer into the pool for loading.

- Prepare transportation casks for unloading by inspecting the cask; removing impact limiters; opening, sampling, and venting the cask; cooling the spent nuclear fuel, and unbolting the cask lid.

- Transfer the cask into a pool for lid removal and transfer of commercial spent nuclear fuel to an empty TAD canister or to a staging rack in the pool. When unloaded, the transportation cask lid(s) would be installed, closed, and bolted in reverse sequence, and the transportation cask would be inspected and surveyed for contamination before transport back to the truck or rail buffer area.

- Manage commercial spent nuclear fuel and blend fuel assemblies to ensure that the loaded TAD canister did not exceed thermal power limits. DOE would transfer loaded TAD canisters that exceeded the waste package thermal power emplacement limits to an aging pad to allow the thermal power to decay to the point where it could load the TAD canister in a waste package and emplace it. The pool would provide limited staging capacity for fuel assemblies.

- Close and seal-weld the loaded TAD canister and transfer it in a shielded transfer cask to a TAD closure station for draining of water from the interior, drying of the interior, evacuation, and helium backfilling. After these steps, the closed TAD canister would be ready for transfer to a Canister Receipt and Closure Facility in a shielded transfer cask for loading in a waste package or an aging overpack.

- Open dual-purpose canisters and transfer the fuel inside the dual-purpose canister to a TAD canister or to the staging rack in the pool.

- Transfer TAD canisters and dual-purpose canisters from shielded transfer casks to aging overpacks and transfer dual-purpose canisters between aging overpacks and shielded transfer casks.

The Wet Handling Facility would handle commercial spent nuclear fuel, uncanistered and in dual-purpose canisters. Transportation casks with uncanistered commercial spent nuclear fuel would move directly into the Wet Handling Facility on the railcars or trucks that transported them to the repository. Rail transportation casks with dual-purpose canisters would move from the railcar buffer area directly into the facility. The facility would have a single pool to transfer commercial spent nuclear fuel from transportation casks and dual-purpose canisters to staging racks for eventual transfer to TAD canisters. Preparation of transportation casks for unloading in the Wet Handling Facility could require the cooling of the casks before their immersion in the pool. A limited quantity of commercial spent nuclear fuel could be temporarily staged in racks in the pool. Normal handling operations would occur under water or in a shielded transfer cask to protect operators from radiological hazards. The facility design includes a high-efficiency particulate air filtration exhaust system to mitigate the consequences of canister drops.

DOE identified Scenarios 5 through 12 (Table E-1) as accident scenarios applicable to operations in the Wet Handling Facility (DIRS 176678-DOE 2006, all).

E.2.1.1.5 *Canister Receipt and Closure Facilities*

The Canister Receipt and Closure Facilities would:

- Receive transportation casks with spent nuclear fuel and high-level radioactive waste in disposable canisters (TAD, dual-purpose, and DOE spent nuclear fuel canisters other than naval spent nuclear fuel canisters, and high-level radioactive waste canisters). In addition, the facility would receive shielded transfer casks with TAD canisters from the Wet Handling Facility and aging overpacks with TAD and dual-purpose canisters from aging pads.
- Prepare transportation casks for unloading by inspecting the cask; removing impact limiters; opening, sampling, and venting the cask; and unbolting the cask lid.
- Transfer the contents of the transportation casks, shielded transfer casks, and aging overpacks into waste packages.
- Transfer TAD and dual-purpose canisters from transportation casks to shielded transfer casks or aging overpacks and transfer them between shielded transfer casks and aging overpacks.
- Install lids on the unloaded transportation casks. The casks would be inspected, decontaminated, and surveyed before transport back to the rail buffer area.
- Install the inner waste package lid and weld it closed; inspect and test the inner lid weld; evacuate the waste package and backfill it with helium; close and seal-weld the backfill port on the inner lid; inspect and test the backfill port closure weld; install the outer waste package lid and weld it closed; inspect, nondestructively examine, test, and stress-relieve the outer lid weld.
- Inspect the completed waste package for physical condition and external radioactive contamination.
- Transfer the waste package to the Transport Emplacement Vehicle.

Each Canister Receipt and Closure Facility would house two shielded, remote canister-handling cells where DOE would transfer TAD canisters from shielded transfer casks or aging overpacks to waste packages. The Department would construct as many as three Canister Receipt and Closure Facilities, each with two waste package closure cells, which would house vertical waste package loading and closing operations. Each facility would have the capability to process TAD or DOE canisters. All transportation casks with high-level radioactive waste and DOE and commercial spent nuclear fuel would move on rail cars directly from the rail buffer area to a Canister Receipt and Closure Facility. An overhead crane would upend and unload the transportation casks from the conveyance. Canister transfers would occur in a vertical orientation using a shielded overhead trolley. A staging area would be in line with each process line.

The Canister Receipt and Closure Facilities would have high-efficiency particulate air filtration exhaust systems to mitigate the consequences of a canister drop.

DOE identified Scenarios 2 through 4 and 9 (Table E-1) as Category 2 accident scenarios applicable to operations in the Canister Receipt and Closure Facility (DIRS 176678-DOE 2006, all).

E.2.1.1.6 *Low-Level Waste Handling Facility*

The Low-Level Waste Facility would accept, manage, and store solid low-level radioactive waste and liquid low-level radioactive waste until shipment off-site for processing. DOE would use standard vehicular transport, such as open flatbed trucks, to move the low-level waste from the surface and subsurface nuclear facilities to the Low-Level Waste Handling Facility. Shielding would be provided as needed. The waste would be stored at the facility in 55-gallon drums, boxes, and bags. The waste would be transferred from onsite storage at the Low-Level Waste Handling Facility to an offsite vendor for processing, disposal, or both at an approved facility. The Low-Level Waste Handling Facility would contain areas for the sorting and storage of waste. DOE identified Scenario 13 (Table E-1) as applicable to the Low-Level Waste Facility (DIRS 176678-DOE 2006, all).

E.2.1.1.7 *Waste Emplacement and Subsurface Facility Systems*

Waste packages would move from the Initial Handling Facility or a Canister Receipt and Closure Facility to the emplacement drifts on a rail-based Transport and Emplacement Vehicle. The waste package would be inside the shielded enclosure of the Transport and Emplacement Vehicle and the vehicle would then descend the North Ramp and proceed to the predetermined emplacement drift. A third-rail electrical system would power the Transport and Emplacement Vehicle. In addition, the transport locomotive has a battery for secondary power. DOE did not identify any accident scenarios for waste emplacement operations (DIRS 176678-DOE 2006, all). However, the Yucca Mountain FEIS identified a transporter runaway accident scenario as a potential event with an estimated frequency of 1.2×10^{-7} per year (DIRS 155970-DOE 2002, Appendix H, p. H-5, Event 19), which is less than the Category 2 threshold of 2×10^{-6} per year. Section E.2.1.1.8 discusses this accident scenario.

E.2.1.1.8 *Beyond-Category-2 Accident Scenarios*

As noted above, DOE evaluated accident scenarios with probabilities of 2×10^{-6} per year or higher for compliance with offsite dose requirements. However, DOE NEPA guidance (DIRS 178579-DOE 2004, p. 28) recommends evaluation of scenarios with probabilities of 1×10^{-7} per year or higher if the impacts could be very large. DOE determined in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Appendix H, p. H-36) that one scenario could fall into this category: Runaway and derailment of the vehicle that would transport waste packages to the emplacement drifts. In this scenario, the waste package would be ejected from the transport vehicle and breached by impact with the ground, which would release radioactive material. DOE has replaced the transporter that the Yucca Mountain FEIS evaluated with a different vehicle, the Transport and Emplacement Vehicle. DOE determined that the probability of a runaway event involving the Transport and Emplacement Vehicle would now be less than 1×10^{-7} per year, which is less than the threshold guidance provided by DOE for reasonably foreseeable events (DIRS 180101-BSC 2007, all). Other beyond-Category-2 events could also occur at the repository. The preliminary hazards analysis lists 26 potential beyond-Category-2 internal events (DIRS 176678-DOE 2006, Table 4-7). However, DOE determined that none of these events would be likely to cause very large offsite consequences because most of the events could occur only in waste handling buildings that have high-efficiency particulate air filtration systems that would limit radionuclide releases. Even if these filtration systems failed, the resulting release would be unlikely to cause very large consequences because of the limited amount of material involved in the event and the retention of radionuclides by the building enclosure. Some of the remaining events could occur in the subsurface areas where a significant fraction of particulate radionuclides could be deposited on surfaces during transport to the atmosphere. For those few accidents that could occur on the surface outside waste handling buildings, none would be likely to result in radioactive releases that resulted in very large offsite consequences because of the limited amount of material involved.

E.2.1.2 Externally Initiated Events

Externally initiated events result either from causes external to the repository (earthquakes, high winds, etc.) or from natural processes that occur over a long period within the repository (corrosion, erosion, etc.). In the Yucca Mountain FEIS, DOE performed an evaluation to identify which of these events could initiate accidents at the repository with the potential for release of radioactive material. Based on this evaluation, DOE concluded that the only external events with a credible potential to release radionuclides of concern would be an aircraft crash and a large (beyond-design-basis) seismic event. The evaluation of both of these externally initialed events has evolved since completion of the FEIS and is described individually below.

E.2.1.2.1 *Aircraft Crash*

For the current repository design, a recent DOE analysis determined that an aircraft crash into repository surface facilities would have a frequency of 7.9×10^{-7} per year (DIRS 178581-BSC 2006, p. 61). While this probability is below the probability threshold of 2×10^{-6} per year and DOE need not consider it in the licensing process (Section E.2.1.1), it is above the DOE NEPA recommended threshold of 1×10^{-7} per year (DIRS 178579-DOE 2004, p. 28) if the consequences could be very large. Therefore, DOE performed a further evaluation of this scenario for this Repository SEIS.

The DOE aircraft crash probability assessment (DIRS 178581-BSC 2006, all) contained several conservative assumptions that tended to produce an upper-bound estimate. For this Repository SEIS, DOE undertook a more realistic evaluation. The conservative assumptions in the DOE assessment were:

- The TAD canister storage modules on the aging pads would be vulnerable to aircraft crash impacts.
- The entire footprint of each waste handling building would be vulnerable in case of an impact. However, only a fraction of the building floor areas would contain spent nuclear fuel and high-level radioactive waste during operations.
- The building walls would be vulnerable during the crash. However, the building walls are thick reinforced concrete and could resist penetration during the crash.

The analysis for this Repository SEIS considered each of these assumptions separately, as follows:

- *Aging Pads*. The aging pads would be concrete pads on which DOE would place TAD and dual-purpose canister aging overpacks. The specification for these aging overpacks (DIRS 182282-DOE

2006, page 20) specifies that the module design would withstand the largest of the most likely aircraft impact, which would be an F-15 fighter aircraft with an impact speed of 150 meters (500 feet) per second. Therefore, DOE removed the storage modules as a target area from the aircraft crash frequency evaluation for this Repository SEIS.

- *Building Footprint*. The analysis for this Repository SEIS reduced the building footprints to include only those areas that would handle spent nuclear fuel and high-level radioactive waste based on floor plans from current design drawings to areas shown to be vulnerable (DIRS 178180-BSC 2006, all; DIRS 178288-BSC 2006, all; DIRS 180278-BSC 2007, all; DIRS 180989-BSC 2007, all). Table E-2 lists the dimension changes.

Table E-2. Surface waste handling building dimensions (meters) for aircraft crash frequency analysis.

Building	DOE frequency analysis[a]		Repository SEIS frequency analysis	
	Length	Width	Length	Width
Initial Handling Facility	93	52	67	21
Canister Receipt and Closure Facility	130	99	100	30
Receipt Facility	99	87	61	21
Wet Handling Facility	120	82	82	32

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Source: DIRS 178581-BSC 2006, p. 26.

- *Concrete walls*. The concrete walls of the buildings would vary in thickness from 1.5 to 1.8 meters (5 to 6 feet) (DIRS 180989-BSC 2007, all; DIRS 180278-BSC 2007, all; DIRS 178180-BSC 2006, all; DIRS 178288-BSC 2006, all). The DOE standard for accident analysis for aircraft crash into Hazardous Facilities (DIRS 101810-DOE 1996, p. 58) evaluated the potential for aircraft parts to penetrate concrete and recommends the following concrete penetration formula:

$$t_p = (U/V)^{0.25}(MV^2/Df_c)^{0.5} \qquad \text{(Equation E-1)}$$

where

t = perforation thickness, or the concrete panel thickness that is just great enough to allow a missile to pass through the panel without any exit velocity (meters)
U = reference velocity [61 meters (200 feet) per second (DIRS 101810-DOE 1996, p. 68)]
V = missile impact velocity (aircraft impact velocity) (meters per second)
M = mass of the missile or the weight (kilograms) divided by gravitational acceleration [9.8 meters (32 feet) per square second)]
D = missile diameter (meters)
f_c = ultimate compressive strength of the concrete (kilograms per square meter)

Small military aircraft from Nellis Air Force Base dominate the probability for aircraft crash (DIRS 178581-BSC 2006, Section 7), and F-15 and F-16 jet fighters make up about 80 percent of the total flights. The aircraft parts with the highest chance of concrete penetration would be the jet engines and engine shafts (DIRS 101810-DOE 1996, p. 58). The relevant characteristics of these engine parts that are relevant to Equation E-1 are an engine mass of about 59 kilograms (130 pounds), an engine diameter of about 1 meter (36 inches), an engine shaft mass of about 0.78 kilogram (1.70 pounds), and an engine shaft diameter of about 7.6 centimeters (3 inches). The ultimate compressive strength of reinforced concrete is

3.5 million kilograms per square meter (720,000 pounds per square foot) (DIRS 101910-Poe 1998, p. 1-4). The assumed impact velocity would be 150 meters (500 feet) per second based on *Standard, Accident Analysis for Aircraft Crash into Hazardous Facilities* (DIRS 101810-DOE 1996, p. C-7), which states that impact velocities would typically be less than 150 meters per second. Using the given values for the parameters in Equation E-1 shows that the engine would produce greater penetration than the engine shaft. For a velocity of 150 meters per second, the F-15 or F-16 jet engine would penetrate about 1 meter (33 inches) of concrete, far less than the 1.5- to 1.8-meter (5- to 6-foot) wall thickness in the current design for the waste handling buildings.

The analysis for this Repository SEIS recalculated the probability of an aircraft crash into waste being handled at the repository using the methods state in *Frequency Analysis of Aircraft Hazards for License Application* (DIRS 178581-BSC 2006, all) and modifying the input to account for the three analysis changes described above. The result was an estimated aircraft crash frequency of 1.5×10^{-8} per year (DIRS 181890-Ashley 2007, all), which is below the DOE-recommended threshold for consideration (DIRS 178579-DOE 2004, p. 29).

Because operations at Nellis Air Force Base include aircraft that carry live ordnance, the analysis considered the possibility of an aircraft crash with ordnance or of jettisoned ordnance striking a waste handling building. However, as the DOE aircraft crash analysis noted (DIRS 178581-BSC 2006, p. 22), carrying ordnance over the flight-restricted airspace around the repository would be prohibited. Therefore, DOE considers this hazard as negligible or nonexistent (DIRS 178581-BSC 2006, p. 61).

Despite this result, and consistent with the Yucca Mountain FEIS, DOE analyzed a scenario in which a jet aircraft impacted and penetrated a Canister Receipt and Closure Facility that contained the maximum inventory of vulnerable commercial spent nuclear fuel. Section E.7 discusses this scenario as a potential sabotage event.

E.2.1.2.2 *Seismic Phenomena*

In the Yucca Mountain FEIS, DOE evaluated a beyond-design-basis earthquake that was assumed to cause the Waste Handling Building to collapse. DOE based the FEIS analysis on the selection of a seismic design basis that specified that structures, systems, and components important to safety (including the Waste Handling Building) should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (DIRS 103237-CRWMS M&O 1998, p. VII-1). For the current design, DOE has performed additional evaluations of the seismic hazard for the repository and revised the seismic design requirements for the facilities. DOE has committed to seismic design criteria and standards that would minimize the potential consequences of seismic events. The Department intends to demonstrate seismic margins for the major structures against earthquake ground motions that are considerably larger than the design-basis ground motion (DIRS 181572-DOE 2007, p. 3-9). Therefore, for this Repository SEIS DOE did not evaluate the consequences of a waste handling building collapse due to a seismic event. However, DOE has determined (DIRS 174261-BSC 2005, Section 6.1.4.4) that a bounding credible seismic event could occur that could cause (1) failure of the high-efficiency particulate air filters and associated ducting and dampers in the waste handling facilities leading to release of accumulated radioactive material, and (2) failure of confinements for the solid and liquid low-level radioactive waste inventories in the Low-Level Waste Handling Facility leading to a release of radioactive material from the low-level radioactive waste.

E.2.2 NONRADIOLOGICAL ACCIDENT SCENARIOS

The potential for a significant release of chemicals or toxic materials during postulated off-normal events at the proposed repository would be very unlikely because the repository would not accept hazardous waste as defined by the *Resource Conservation and Recovery Act of 1976* (42 U.S.C. 6901 et seq.) and 40 CFR Part 261, "Protection of Environment: Identification and Listing of Hazardous Waste."

Hazardous and toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as sulfuric acid, hydrocarbons (including fuels, oils, and lubricants), and various solid chemicals. These substances are in common use at other DOE sites. DOE evaluated the potential for impacts to workers from the handling of hazardous and toxic materials as part of the industrial health and safety analysis in Chapter 4, Section 4.1.7.1 of this Repository SEIS. That analysis estimated the impacts to workers from industrial hazards using DOE accident experience at other sites, which include impacts from hazardous materials and toxic substances as part of typical DOE operations.

Impacts to members of the public would be unlikely. Because the hazardous materials would be mostly liquid and solid rather than gaseous, a release would not transport the materials off the repository site. The potential for hazardous chemicals to reach surface water would be limited to spills or leaks that occurred just before a rare precipitation or snowmelt event large enough to generate runoff. DOE would use engineered measures to minimize the potential for spills or releases of hazardous chemicals throughout the project. These plans and procedures would ensure the proper management and remediation of spills. Therefore, the generation, storage, packaging, and shipment off the site of solid and liquid hazardous waste would present a very small potential for accidental releases and exposures of workers or the public.

E.3 Source Terms for Repository Accident Scenarios

DOE estimated source terms for each accident scenario the analysis retained (Table E-1). The source term is an estimate of the amount of radioactive material an accident could release, which partially determines the estimated radiological impacts from accident scenarios. The source term includes several factors: the materials at risk (the total inventory of radioactive materials the scenario could involve), the quantity of the release of those materials; the elevation of the release; the chemical and physical forms of the released materials; and the energy (if any) of the plume that would carry the radionuclides to the environment. These factors would vary according to the state of the material at the time and the extent and type of damage that would initiate the release. In addition, the analysis of the source terms considered measures that would reduce the amount of the release to the environment, such as filtration systems and local deposition of radionuclides.

For accident releases that pass through high-efficiency particulate air filters, DOE assumed a retention factor of 0.99 for each filter stage for particulates and cesium (DIRS 174261-BSC 2005, p. 37). Therefore, for the two-stage filter systems in the Initial Handling Facility, Wet Handling Facility, Canister Receipt and Closure Facility, and Receipt Facility, the filters would reduce airborne particulates by a factor of 10,000.

E.3.1 NAVAL SPENT NUCLEAR FUEL

The drop (or fall) of a naval spent nuclear fuel canister (Scenario 1, Table E-1) could result in a breach of the canister and release of radionuclides contained with the spent fuel in the canister. Table E-3 lists the total airborne activity estimated by the Navy to be released (DIRS 182094-McKenzie 2007, Table 1.8-9). The Navy also estimated the fraction of the total release that would be respirable. However, for conservatism, the analysis assumed that all of the airborne release would be respirable, consistent with the assumption in *Preclosure Consequence Analyses for License Application* (DIRS 174261-BSC 2005, p. 69).

Table E-3. Total airborne activity release by radionuclide for drop of naval canister (curies).

Radionuclide	Total airborne activity release
Actinium-227	1.2×10^{-9}
Americium-241	4.2×10^{-4}
Americium-242m	4.7×10^{-6}
Americium-243	6.1×10^{-6}
Antimony-125	2.5×10^{-2}
Barium-137m	3.6×10^{0}
Cadmium-113m	3.2×10^{-4}
Californium-252	6.6×10^{-11}
Carbon-14	1.7×10^{-1}
Cesium-134	4.8×10^{0}
Cesium-135	2.7×10^{-4}
Cesium-137	2.5×10^{1}
Cobalt-60	5.3×10^{-1}
Curium-242	1.3×10^{-5}
Curium-243	7.0×10^{-6}
Curium-244	5.8×10^{-4}
Curium-245	4.7×10^{-8}
Curium-246	1.2×10^{-8}
Curium-247	3.1×10^{-13}
Curium-248	1.0×10^{-12}
Europium-154	9.2×10^{-2}
Europium-155	1.8×10^{-2}
Hydrogen-3	1.1×10^{2}
Iodine-129	1.1×10^{-2}
Iron-55	5.7×10^{-1}
Krypton-85	3.0×10^{3}
Lead-210	1.0×10^{-11}
Neptunium-237	1.5×10^{-5}
Nickel-59	3.0×10^{-3}
Nickel-63	2.9×10^{-1}
Niobium-93m	1.2×10^{-2}

Radionuclide	Total airborne activity release
Niobium-94	2.6×10^{-3}
Palladium-107	5.2×10^{-7}
Plutonium-238	1.1×10^{-1}
Plutonium-239	1.1×10^{-4}
Plutonium-240	1.4×10^{-4}
Plutonium-241	3.3×10^{-2}
Plutonium-242	7.8×10^{-7}
Promethium-147	1.2×10^{0}
Protactinium-231	5.9×10^{-9}
Radon-226	6.3×10^{-11}
Radon-228	4.6×10^{-15}
Rhodium-102	2.1×10^{-7}
Ruthenium-106	2.9×10^{-1}
Samarium-147	2.7×10^{-10}
Samarium-151	1.1×10^{-2}
Scandium-79	2.9×10^{-6}
Strontium-90	3.7×10^{0}
Technetium-99	6.1×10^{-4}
Thorium-229	7.3×10^{-11}
Thorium-230	1.9×10^{-8}
Thorium-232	9.8×10^{-13}
Tin-126	1.0×10^{-5}
Uranium-232	3.8×10^{-6}
Uranium-233	9.8×10^{-9}
Uranium-234	1.4×10^{-4}
Uranium-235	2.2×10^{-6}
Uranium-236	2.2×10^{-5}
Uranium-238	8.7×10^{-9}
Yttrium-90	3.7×10^{0}
Zirconium-93	6.5×10^{-5}

E.3.2 HIGH-LEVEL RADIOACTIVE WASTE

High-level radioactive waste in vitrified form would arrive at the repository in sealed canisters inside transportation casks from the Savannah River Site, the Hanford Site, the West Valley Demonstration Project, and the Idaho National Laboratory. The analysis used Savannah River Site high-level waste to represent the materials at risk because it would have the highest dose consequences (DIRS 174261-BSC 2005, p. 72). Table E-4 lists the materials at risk per canister.

Table E-4. Materials at risk for high-level radioactive waste canisters (curies).

Radionuclide	Total airborne activity release	Radionuclide	Total airborne activity release
Antimony-125	1.2×10^{2}	Plutonium-238	9.9×10^{2}
Americium-241	3.3×10^{2}	Plutonium-239	1.7×10^{1}
Americium-242m	7.8×10^{-2}	Plutonium-240	8.4×10^{0}
Americium-243	1.4×10^{0}	Plutonium-241	8.4×10^{2}
Barium-137m	5.3×10^{4}	Plutonium-242	2.1×10^{-2}
Cadmium-113	2.6×10^{-11}	Praseodymium-144m	3.8×10^{0}
Californium-249	2.3×10^{-2}	Promethium-147	2.2×10^{3}
Californium-251	1.9×10^{-2}	Ruthenium-106	4.4×10^{0}
Cerium-144	3.8×10^{0}	Samarium-151	1.6×10^{2}
Cesium-134	2.0×10^{2}	Selenium-79	5.3×10^{-1}
Cesium-135	2.2×10^{-1}	Strontium-90	3.4×10^{4}
Cesium-137	5.6×10^{4}	Technetium-99	9.2×10^{0}
Cobalt-60	1.9×10^{2}	Thorium-229	8.9×10^{-5}
Curium-243	4.2×10^{-1}	Thorium-230	8.0×10^{-6}
Curium-244	4.4×10^{2}	Thorium-232	1.4×10^{-3}
Curium-245	2.4×10^{-2}	Tin-121m	1.9×10^{0}
Curium-246	2.9×10^{-2}	Tin-126	7.8×10^{-1}
Curium-247	2.2×10^{-2}	Uranium-232	3.0×10^{-4}
Europium-154	4.2×10^{2}	Uranium-233	5.6×10^{-2}
Europium-155	6.8×10^{-1}	Uranium-234	4.5×10^{-2}
Iodine-129	3.2×10^{-4}	Uranium-235	6.6×10^{-4}
Neptunium-237	2.9×10^{-2}	Uranium-236	3.7×10^{-3}
Nickel-59	8.4×10^{-1}	Uranium-238	4.7×10^{-2}
Nickel-63	8.0×10^{1}	Yttrium-90	3.4×10^{4}
Niobium-93m	1.5×10^{-1}	Zirconium-93	3.9×10^{-1}
Palladium-107	1.3×10^{-3}		

Source: DIRS 181690-Ray 2007, Table 2, Column 3.

The analysis established the airborne release fraction of the materials at risk to calculate the doses to workers and members of the public based on the method described in Yucca Mountain Project correspondence (DIRS 182924-Wisenburg 2007, all). The high-level radioactive waste release fraction would consist of pulverized particles that would result from an impact and breach of a high-level radioactive waste canister. The release fraction *PULF* is a function of the drop height of the high-level radioactive waste canister:

$$PULF = 2 \times 10^{-4} \text{ cubic centimeters per joule} \times E/V \qquad \text{(Equation E-2)}$$

where

PULF = fraction of crud release pulverized to respirable size (less than 10 micrometers in diameter) from a drop scenario

E/V = impact energy density in high-level radioactive waste
= 1×10^{-7} joule-square second per gram-square centimeter × $p \times g \times h$
where
p = density of the high-level radioactive waste, 2.75 gram per cubic centimeter (DIRS 174261-BSC 2005, all)
g = gravitational constant, 980.7 centimeters per square second (DIRS 174261-BSC 2005, all)
h = drop height in centimeters.

For the high-level radioactive waste drop (Scenario 3 from Table E-1), the drop height would be 1,138 centimeters (448 inches) (DIRS 174261-BSC 2005, p. 75). This drop height is conservative because the handling system design would have a maximum drop height for an unsealed waste package with high-level radioactive of 710 centimeters (276 inches) (DIRS 174261-BSC 2005, all). Using a drop height of 1,138 centimeters results in a respirable fraction of

$$PULF = (2 \times 10^{-4}) \times (1.0 \times 10^{-7}) \times 2.75 \times 980.7 \times 1{,}138 = 6.14 \times 10^{-5} \qquad \text{(Equation E-3)}$$

The value in Equation E-3 was rounded up to 7.0×10^{-5}.

For the three accident scenarios that would involve high-level radioactive waste (Scenarios 2, 3, and 4, Table E-1), the analysis applied a leak path factor (DIRS 176678-DOE 2006, p. 4-33, footnote c). This factor accounts for deposition of particles in the leakage path out of the canisters or cask. For Scenario 2, the analysis applied a leak path factor of 0.01 to account for the leak path out of the high-level radioactive waste canister (0.1) and then out of the transportation cask (0.1). For Scenarios 3 and 4, the analysis used a leak path factor of 0.1 to account for the canister leak path. Therefore, for particulate releases, the respirable airborne release fractions for scenarios that involved high-level radioactive waste would be:

Scenario 2 = 5 canisters × 0.01 × 7 × 10^{-5} = 3.5×10^{-6}
Scenario 3 = 5 canisters × 0.1 × 7 × 10^{-5} = 3.5×10^{-5}
Scenario 4 = 2 canisters × 0.1 × 7 × 10^{-5} = 1.4×10^{-5}

The analysis applied these values to the materials at risk radionuclide values from Table E-2 and used the results to calculate the consequences from the high-level radioactive waste drop scenario.

E.3.3 COMMERCIAL SPENT NUCLEAR FUEL DROP

Scenarios 5 to 12 would involve releases from commercial spent nuclear fuel assemblies when the assemblies were damaged during an accident. The releases would consist of fuel and crud. For the analysis in this Repository SEIS, DOE chose to use the maximum fuel characteristics. This selection helps ensure that the calculated consequences would encompass those of commercial spent nuclear fuel received at the repository and that the results would be conservative and not underestimated. Table E-5 lists maximum fuel characteristics.

Previous analyses determined that the consequences of accidents that involved pressurized-water reactor fuel assemblies would be higher than those that involved boiling-water reactor assemblies. For the maximum fuel, the preclosure consequence analysis (DIRS 174261-BSC 2005, p. 40) validates this conclusion.

Table E-5. Maximum commercial boiling- and pressurized-water reactor spent nuclear fuel characteristics.

Commercial SNF assembly	Initial enrichment (%)	Burnup (GWd/MTU)	Decay time (years)
Maximum PWR	5.0	80	5
Maximum BWR	5.0	75	5

BWR = Boiling-water reactor.
GWd = Gigawatt-day.
MTU = Metric ton of uranium.
SNF = Spent nuclear fuel.
PWR = Pressurized-water reactor.

E.3.3.1 Fuel Release

As noted in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Appendix H, p. H-24), commercial spent nuclear fuel contains nearly 400 radionuclides. Not all of these, however, would be important in terms of a potential to cause adverse health effects, and many would have decayed to minor quantities by the time the material arrived at the repository. For the SEIS, DOE performed an assessment and identified 50 radionuclides as part of the inventory that would contribute to offsite consequences from a release (DIRS 180185-BSC 2007, Attachment II). Table E-6 lists the inventory for the consequences analysis for pressurized-water reactor fuel based on the maximum fuel characteristics in Table E-5.

Table E-6. Inventory for maximum commercial spent nuclear fuel (curies per assembly).

Radionuclide	Total airborne activity release	Radionuclide	Total airborne activity release
Americium-241	8.8×10^{2}	Niobium-93m	3.9×10^{-1}
Americium-242	1.0×10^{1}	Niobium-94	1.0×10^{-4}
Americium-242m	1.0×10^{1}	Palladium-107	1.6×10^{-1}
Americium-243	6.0×10^{1}	Plutonium-238	6.8×10^{3}
Antimony-125	1.9×10^{3}	Plutonium-239	1.8×10^{2}
Barium-137m	9.9×10^{4}	Plutonium-240	4.0×10^{2}
Cadmium-113m	3.8×10^{1}	Plutonium-241	8.0×10^{4}
Carbon-14	5.4×10^{-1}	Plutonium-242	3.3
Cesium-134	4.1×10^{4}	Promethium-147	2.3×10^{4}
Cesium-135	6.3×10^{-1}	Protactinium-231	4.2×10^{-5}
Cesium-137	1.1×10^{5}	Ruthenium-106	1.3×10^{4}
Chlorine-36	1.1×10^{-2}	Samarium-151	3.2×10^{2}
Cobalt-60[a]	3.3×10^{1}	Selenium-79	7.4×10^{-2}
Curium-242	3.6×10^{1}	Strontium-90	6.5×10^{4}
Curium-243	4.2×10^{1}	Technetium-99	1.3×10^{1}
Curium-244	1.4×10^{4}	Thorium-230	3.3×10^{-5}
Curium-245	1.8	Tin-126	6.8×10^{-1}
Curium-246	1.2	Uranium-232	6.0×10^{-2}
Europium-154	6.2×10^{3}	Uranium-233	2.4×10^{-5}
Europium-155	1.8×10^{3}	Uranium-234	5.2×10^{-1}
Hydrogen-3	5.0×10^{2}	Uranium-235	3.3×10^{-3}
Iodine-129	3.6×10^{-2}	Uranium-236	2.2×10^{-1}
Iron-55[(a)]	7.5×10^{2}	Uranium-238	1.4×10^{-1}
Krypton-85	5.8×10^{3}	Yttrium-90	6.5×10^{4}
Neptunium-237	4.0×10^{-2}	Zirconium-93	1.3

a. Buildup of activated components (crud) contained on fuel assembly surfaces.

To calculate the consequences from a commercial spent nuclear fuel drop accident scenario, it is necessary to derive an airborne respirable release fraction to apply to the inventory. For accidents that happened in air, the release fractions would have two components—burst release fraction and oxidation release fraction. The burst release fraction would be that fraction that was released immediately when the commercial spent nuclear fuel rod ruptured as a result of the drop. This fraction would consist of the releasable material in the fuel pin gap plus additional particles that were produced by fragmentation of the fuel pellets from the mechanical impact of the drop. The oxidation release fraction would occur when the hot fuel pellets were exposed to air and became oxidized, producing a powder (DIRS 173261-BSC 2005, all). This release fraction would be produced over a longer period (up to 30 days). Table E-7 lists the release fractions for these components (DIRS 182924-Wisenburg 2007, all). Some releases could involve locations where high-efficiency particulate air filtration of the material would be available before release to the atmosphere. The table indicates the airborne release fraction for cases with and without high-efficiency particulate air filtration.

Table E-7. Release fractions for commercial spent nuclear fuel drop accident scenarios.

	Burst release			
Radionuclide	RARF without HEPA[a]	RARF with HEPA[b]	Oxidation release-RARF with HEPA[c]	Accident scenarios (Table E-1)[d]
Hydrogen-3	3.0×10^{-1}	3.0×10^{-1}	7.0×10^{-1}	5 to 12
Krypton-85	3.0×10^{-1}	3.0×10^{-1}	3.0×10^{-1}	5 to 12
Iodine-129	3.0×10^{-1}	3.0×10^{-1}	3.0×10^{-1}	5 to 12
Cesium	2.0×10^{-3}	2.0×10^{-7}	2×10^{-7}	5, 7, 9
Strontium[e]	3.0×10^{-5}	3.0×10^{-9}	2×10^{-7}	5, 7, 9
Ruthenium	2.0×10^{-3}	2.0×10^{-7}	2×10^{-7}	5, 7, 9
Crud[e]	1.5×10^{-2}	1.5×10^{-6}	0	5, 7, 9
Fuel fines[e]	3.0×10^{-5}	3.0×10^{-9}	2×10^{-7}	5, 7, 9

a. Source: DIRS 182924-Wisenburg 2007, all
b. Factor of 1×10^{-4} applied per DIRS 176678-DOE 2006, p. B-12.
c. Factor of 1×10^{-4} applied per DIRS 176678-DOE 2006, p. B-9.
d. These scenarios would occur where HEPA filtration was operating.
e. See Section E.3.3.2 for crud component.
HEPA = High-efficiency particulate air (filter).
RARF = Respirable airborne release fraction.

The analysis applied the release fractions from Table E-7 to the radionuclide inventories in Table E-6 to calculate the respirable airborne release fractions for those accident scenarios that involved commercial spent nuclear fuel in an air environment (5, 7, and 9).

For accident scenarios that would occur in the pool of the Wet Handling Facility (8, 10, 11, and 12), the analysis assumed release of only gaseous radionuclides because the particulates would be trapped by the water above the commercial spent nuclear fuel assemblies (DIRS 176678-DOE 2006, p. B-3) and would not be available for release. Consistent with the preliminary hazards analysis (DIRS 176678-DOE 2006, p. B-3), the analysis for this Repository SEIS assumed release fractions of 1.0 (100 percent) for krypton-85, hydrogen-3, carbon-14, and chlorine-36, and 0.005 for iodine-129. Absorption in the water would reduce the iodine-129 release.

E.3.3.2 Crud

During nuclear power reactor operation, crud (corrosion material) builds up on the outside of the fuel rod assembly surfaces and becomes radioactive from neutron activation. An accident could dislodge crud from those surfaces. After decaying for 5 years, the nuclide species that have significant activity in the crud for commercial spent nuclear fuel are iron-55 and cobalt-60. Table E-8 provides the crud activity per assembly at the time of discharge from the reactor (DIRS 176678-DOE 2006, p. B-8), and after 5 years of decay (DIRS 174261-BSC 2005, Table 15). The analysis assumed that the fraction of crud release in a drop accident scenario would be 0.015 (DIRS 176678-DOE 2006, p. B-9), all of which would be respirable.

Table E-8. Pressurized-water reactor commercial spent nuclear fuel crud activities (curies per assembly).

	Inventory					
	At discharge		At 5 years		Respirable amount (5-year-old fuel)	
Radionuclide	PWR	BWR	PWR	BWR	PWR	BWR
Iron-55	2.7×10^3	1.3×10^3	7.5×10^2	3.5×10^2	11	5.3
Cobalt-60	63	2.1×10^2	33	1.1×10^2	0.49	1.6

PWR = Pressurized-water reactor.
BWR = Boiling-water reactor.

E.3.4 LOW-LEVEL WASTE FIRE

Several operations at the proposed repository would produce low-level radioactive waste, which the Low-Level Waste Facility would receive for shipment off the site. The accident scenario the analysis identified for this facility (Scenario 13, Table E-1) would be a fire that involved combustion of the combustible portion of the dry active waste stored at the Low-Level Waste Handling Facility. The source term for this scenario would be 0.034 curie per cubic meter (DIRS 182584-BSC 2007, Table 9). Table E-9 lists the distribution of radionuclides released from the fire event as developed in *Preclosure Consequence Analyses for License Application* (DIRS 174261-BSC 2005, all).

Table E-9. Respirable airborne release for low-level radioactive waste fire.

Radionuclide	Respirable airborne release (curies)
Cesium-134	2.0×10^{-3}
Cesium-137	2.2×10^{-3}
Cobalt-58	1.7×10^{-3}
Cobalt-60	4.4×10^{-3}
Manganese-54	2.3×10^{-4}

Source: DIRS 174261-BSC 2005, Appendix II, Table 5.

E.3.5 SEISMIC EVENT

This event would involve failure of the high-efficiency particulate air filters and associated ducting and dampers as well as failure of the confinement function for the solid and liquid low-level radioactive waste. Airborne release fractions for this event are based on values for free-fall spills (DIRS 174261-BSC 2005, all) taken from the DOE handbook on release fractions (DIRS 103756-DOE 1994, all). Free-fall spill release fractions are used for the seismic event releases because the collapse of structures and components or falling debris onto materials would be equivalent to a crush or impact event or a free-fall of the material onto an unyielding surface. The development of the release fractions considered multiple seismic release effects including shock vibration, structure collapse, and debris turbulence. (Details are provided in DIRS 174261-BSC 2005, all.) The release fractions for estimating accumulation of particulate radionuclides on high-efficiency particulate air filters and associated ducting and dampers are 2.0×10^{-4} for cesium and ruthenium, 1.5×10^{-2} for the crud components (cobalt and iron), and 3.0×10^{-5} for all remaining particulate radionuclides. Because barium-137m would be in equilibrium with cesium-137 on the filters, the release for the seismic event is set equal to that of cesium-137. DOE based the estimate of the amount of accumulated radiological material available for release on the basis of: (1) commercial spent nuclear fuel would be received at an average rate of 630 fuel assemblies per month (based on 3,600 metric tons per year with each fuel assembly equivalent to 475 kilograms), (2) 10 percent of these (36 per month) are assumed to be handled as uncanistered fuel assemblies (and thus are available to release radionuclides during normal operations), and (3) 1 percent are defective (resulting in a release that is accumulated on the ducts and filters). An airborne release fraction of 1.0×10^{-2} is applied to the accumulated inventory based on releases from unenclosed filter media during a seismic event sequence from *Analysis of Experimental Data, Volume 1* of *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DIRS 103756-DOE 1994, Section 5.4.4.). The fuel assumed for this event is the representative pressurized-water reactor fuel assembly developed for normal operations releases. Table E-10 lists the source term for this event. The table gives the radionuclide inventory for the representative fuel assembly in the second column. The fourth column gives the filter buildup rate, which was calculated by the product of the curies per spent fuel assembly in the second column multiplied by 36 fuel assemblies per month, the airborne release fraction in the third column, and a factor of 0.01 for the defective fuel fraction. The fifth column gives the buildup after 18 months, and the sixth column is the amount released from the filters (1 percent of the 18-month buildup quantity). The seismic event is also assumed to release radionuclides from the Low-Level Waste Handling Facility and include releases from high-integrity containers, drums, boxes, and tanks containing liquid low-level radioactive waste. Details of this release estimate are provided in Yucca Mountain Project correspondence (DIRS 182924-Wisenburg 2007, all). The Low-Level Waste Handling Facility respirable airborne release includes five radionuclides; their activity is listed in the seventh column in Table E-10. This activity and is added to the corresponding high-efficiency particulate air filter release t o provide the total respirable airborne release (last column).

E.4 Accident Scenario Consequences

E.4.1 GENERAL METHODOLOGY

The analysis calculated the radiological accident scenario consequences as individual doses (rem), collective doses (person-rem), and latent cancer fatalities. It considered the following individuals: (1) the maximally exposed offsite individual, who is a hypothetical member of the public at the point on the analyzed land withdrawal area boundary who would receive the largest dose from the assumed accident scenario, which is either about 18.5 kilometers (11 miles) southeast of the repository site or 7.8 kilometers (4.8 miles) east of the site, (2) the noninvolved worker, or the hypothetical worker near the accident, who would be 60 meters (180 feet) from the release point, and (3) members of the public who resided within about 80 kilometers (50 miles) of the proposed repository in 2067 (Chapter 3, Figure 3-16). The 60-meter distance for the noninvolved worker is less than the 100 meters (330 feet) DOE used in the Yucca Mountain FEIS because the current design places exclusion fences 60 meters from the facilities. This analysis did not calculate doses to involved workers for the following reasons: (1) for releases in waste handling buildings (scenarios 1 through 12), operators would be in enclosed operating areas that would isolate them from a release; (2) for scenario 13 (fire involving low-level radioactive waste), the fire would cause the release to be lofted into the atmosphere such that workers close to the release would not be receive meaningful exposure; and (3) for scenario 14 (seismic event), workers inside the Low-Level

Table E-10. Source term (curies) for bounding seismic event.

Radionuclide	Representative PWR (curies/SFA)	Fuel ARF	HEPA filter buildup rate (curies/ month)	HEPA filter buildup-18 months	HEPA filter seismic release (curies)	LLW seismic release (curies)	Total seismic release
Americium-241	1.2×10^{3}	3.0×10^{-5}	2.2×10^{-2}	4.0×10^{-1}	4.0×10^{-3}	0	4.0×10^{-3}
Americium-242	7.3	3.0×10^{-5}	1.4×10^{-4}	2.5×10^{-3}	2.5×10^{-5}	0	2.5×10^{-4}
Americium-242m	7.3	3.0×10^{-5}	1.4×10^{-4}	2.5×10^{-4}	2.5×10^{-4}	0	2.5×10^{-4}
Americium-243	23	3.0×10^{-5}	4.4×10^{-4}	7.8×10^{-3}	7.8×10^{-5}	0	7.8×10^{-5}
Antimony-125	3.9×10^{2}	3.0×10^{-5}	7.4×10^{-3}	0.13	1.3×10^{-3}	0	1.3×10^{-3}
Barium-137m	5.7×10^{4}	2.0×10^{-4}	7.2	$1.3 \times 10^{+2}$	1.3	0	1.3
Cadmium-113m	14	3.0×10^{-5}	2.6×10^{-4}	4.7×10^{-3}	4.7×10^{-5}	0	4.7×10^{-5}
Carbon-14	0.42	0.3	0	0	0	0	0
Cerium-144	73	3.0×10^{-5}	1.4×10^{-3}	2.5×10^{-2}	2.5×10^{-4}	0	2.5×10^{-4}
Cesium-134	4.1×10^{3}	2.0×10^{-4}	0.52	9.3	9.3×10^{-2}	6.0	6.1
Cesium-135	0.37	2.0×10^{-4}	4.7×10^{-5}	8.5×10^{-4}	8.5×10^{-6}	0	8.5×10^{-6}
Cesium-137	6.0×10^{4}	2.0×10^{-4}	7.6	$1.4 \times 10^{+2}$	1.4	6.8	8.2
Chlorine-36	8.5×10^{-3}	0.3	0	0	0	0	0
Cobalt-58	0	-		0		2.8	2.8
Cobalt-60	17	1.5×10^{-2}	0.16	2.9	2.9×10^{-2}	7.2	7.2
Curium-242	6.0	3.0×10^{-5}	1.1×10^{-4}	2.1×10^{-3}	2.1×10^{-5}	0	2.1×10^{-5}
Curium-243	16	3.0×10^{-5}	3.0×10^{-4}	5.4×10^{-3}	5.4×10^{-5}	0	5.4×10^{-5}
Curium-244	2.6×10^{3}	3.0×10^{-5}	4.9×10^{-2}	8.8×10^{-1}	8.8×10^{-3}	0	8.8×10^{-3}
Curium-245	0.34	3.0×10^{-5}	6.4×10^{-6}	1.2×10^{-4}	1.2×10^{-6}	0	1.2×10^{-6}
Curium-246	0.12	3.0×10^{-5}	2.2×10^{-6}	4.0×10^{-5}	4.0×10^{-7}	0	4.0×10^{-7}
Europium-154	2.4×10^{3}	3.0×10^{-5}	4.5×10^{-2}	0.81	8.1×10^{-3}	0	8.1×10^{-3}
Europium-155	4.9×10^{2}	3.0×10^{-5}	9.4×10^{-3}	0.17	1.7×10^{-3}	0	1.7×10^{-3}
Hydrogen-3	2.4×10^{2}	0.3	0	0	0	0	0
Iodine-129	2.3×10^{-2}	0.3	0	0	0	0	0
Iron-55	2.1×10^{2}	1.5×10^{-2}	2.0	36	0.36	0	0.36
Krypton-85	3.1×10^{3}	0.3	0	0	0	0	0
Manganese-54	0	-		0	0	1.2	1.2
Neptunium-237	0.25	3.0×10^{-5}	4.8×10^{-6}	8.6×10^{-5}	8.6×10^{-7}	0	8.6×10^{-7}
Neptunium-239	23	3.0×10^{-5}	4.4×10^{-4}	7.8×10^{-3}	7.8×10^{-5}	0	7.8×10^{-5}
Niobium-93m	0.34	3.0×10^{-5}	6.5×10^{-6}	1.2×10^{-4}	1.2×10^{-6}	0	1.2×10^{-6}
Niobium-94	6.3×10^{-5}	3.0×10^{-5}	1.2×10^{-9}	2.2×10^{-8}	2.2×10^{-10}	0	2.2×10^{-10}
Paladium-107	8.7×10^{-2}	3.0×10^{-5}	1.6×10^{-6}	3.0×10^{-5}	3.0×10^{-7}	0	3.0×10^{-7}
Plutonium-238	2.8×10^{3}	3.0×10^{-5}	5.3×10^{-2}	0.95	9.5×10^{-3}	0	9.5×10^{-3}
Plutonium-239	1.8×10^{2}	3.0×10^{-5}	3.4×10^{-3}	6.1×10^{-2}	6.1×10^{-4}	0	6.1×10^{-4}
Plutonium-240	3.2×10^{2}	3.0×10^{-5}	6.1×10^{-3}	0.11	1.1×10^{-3}	0	1.1×10^{-3}
Plutonium-241	5.2×10^{4}	3.0×10^{-5}	0.99	18	0.18	0	0.18
Plutonium-242	1.7	3.0×10^{-5}	3.2×10^{-5}	5.7×10^{-4}	5.7×10^{-5}	0	5.7×10^{-6}
Praseodymium-144	73	3.0×10^{-5}	1.4×10^{-3}	2.5×10^{-2}	2.5×10^{-4}	0	2.5×10^{-4}
Promethium-147	6.4×10^{3}	3.0×10^{-5}	0.21	2.2	2.2×10^{-2}	0	2.2×10^{-2}
Protactinium-231	3.0×10^{-5}	3.0×10^{-5}	5.7×10^{-10}	1.0×10^{-8}	1.0×10^{-10}	0	1.0×10^{-10}
Ruthenium-106	3.4×10^{2}	2.0×10^{-4}	4.3×10^{-2}	0.77	7.7×10^{-3}	0	7.7×10^{-3}
Samarium-151	2.5×10^{2}	3.0×10^{-5}	4.6×10^{-3}	8.4×10^{-2}	8.4×10^{-4}	0	8.4×10^{-4}
Selenium-79	4.8×10^{-2}	3.0×10^{-5}	9.0×10^{-7}	1.6×10^{-5}	1.6×10^{-7}	0	1.6×10^{-7}
Strontium-90	4.1×10^{4}	3.0×10^{-5}	0.78	14	0.14	0	0.14
Technetium-99	9.3	3.0×10^{-5}	1.8×10^{-4}	3.2×10^{-3}	3.2×10^{-5}	0	3.2×10^{-5}
Thorium-230	6.5×10^{-5}	3.0×10^{-5}	1.2×10^{-9}	2.2×10^{-8}	2.2×10^{-10}	0	2.2×10^{-10}
Tin-126	0.40	3.0×10^{-5}	7.5×10^{-6}	1.4×10^{-4}	1.4×10^{-6}	0	1.4×10^{-6}
Uranium-232	2.4×10^{-2}	3.0×10^{-5}	4.6×10^{-7}	8.3×10^{-6}	8.3×10^{-8}	0	8.3×10^{-8}

Table E-10. Source term (curies) for bounding seismic event (continued).

Radionuclide	Representative PWR (curies/SFA)	Fuel ARF	HEPA filter buildup rate (curies/ month)	HEPA filter buildup-18 months	HEPA filter seismic release (curies)	LLW seismic release (curies)	Total seismic release
Uranium-233	2.5×10^{-5}	3.0×10^{-5}	4.7×10^{-10}	8.4×10^{-9}	8.4×10^{-11}	0	8.4×10^{-11}
Uranium-234	0.60	3.0×10^{-5}	1.1×10^{-5}	2.1×10^{-4}	2.1×10^{-6}	0	2.1×10^{-6}
Uranium-235	7.7×10^{-3}	3.0×10^{-5}	1.5×10^{-7}	2.6×10^{-6}	2.6×10^{-8}	0	2.6×10^{-8}
Uranium-236	0.18	3.0×10^{-5}	3.4×10^{-6}	6.2×10^{-5}	6.2×10^{-7}	0	6.2×10^{-7}
Uranium-238	0.15	3.0×10^{-5}	2.8×10^{-6}	5.0×10^{-5}	5.0×10^{-7}	0	5.0×10^{-7}
Yttrium-90	4.1×10^{4}	3.0×10^{-5}	0.78	14	0.14	0	0.14
Zirconium-93	0.83	3.0×10^{-5}	1.6×10^{-5}	2.8×10^{-4}	2.8×10^{-6}	0	2.8×10^{-6}

ARF = Respirable airborne release fraction.
HEPA = High-efficiency particulate air (filter).
LLW = Low-level radioactive waste.
SFA = Spent fuel assembly.
PWR = Pressurized-water reactor.

Waste Handling Facility would likely be injured or killed as a result of the event, and the dose to the noninvolved worker at 60 meters (200 feet) would be representative of the dose to involved workers outside the facility. Appendix D, Section D.1 discusses the health effects of radiation doses.

The analysis used the GENII computer program (DIRS 100953-Napier et al. 1988, all) and the radionuclide source terms for the identified accident scenarios to calculate consequences to individuals and populations. The GENII program, developed by the U.S. Environmental Protection Agency at Pacific Northwest National Laboratory, has been widely used to compute radiological impacts from accident scenarios that involve releases of radionuclides. The analysis used this program to calculate doses for offsite members of the public, the maximally exposed offsite individual, and the noninvolved worker. The GENII program calculates radiological doses based on input meteorological conditions. The analysis used 95th-percentile and 50th-percentile Yucca Mountain sector-specific weather conditions for 2001 to 2005; 16 radial sectors were used to represent areas affected by wind direction from the repository. Atmospheric dispersion factors (dilution of the plume as a function of weather and distance from the release point) were calculated with the methodology in *General Public Atmospheric Dispersion Factors* (DIRS 177510-BSC 2007, all) for site boundary doses and for collective population doses.

The GENII program evaluates doses from various pathways including direct radiation from the radioactive plume produced by the accident, inhalation of radioactive material in the plume, direct exposure from radionuclides that are deposited on soil (groundshine), ingestion of food products that become contaminated with radionuclides deposited from the plume, and exposure from radionuclides that are resuspended from the ground. The dose calculations included all of these pathways for the site boundary and 80-kilometer (50-mile) population doses. For the noninvolved worker, the analysis conservatively assumed the worker would evacuate within 8 hours (DIRS 176678-DOE 2006, p. B-11), so only direct exposure, inhalation from the plume, and groundshine for 8 hours were factors. Site-Specific Input Files for Use with GENII Version 2 (DIRS 177751-BSC 2007, all) provides details on the input data for the analysis. For the maximum site boundary dose, calculations included a hypothetical individual 18.5 kilometers (11 miles) southeast of the repository and 7.8 kilometers (4.8 miles) east of the repository. These two locations were determined to be the locations producing the highest site boundary dose based on sector-specific meteorology.

For facilities with high-efficiency-particulate-air filtration systems, the analysis in this Repository SEIS credits the filtration provided during an accident. In some cases (Initial Handling Facility), the results are also presented to provide the consequences of the same accident if filtration were not credited. These results illustrate that some filtration systems may not be required to meet regulatory standards, however, since they are included in the current facility design, DOE has included their availability in the assessment of accident consequences.

For exposure to inhaled and ingested radioactive material, the analysis assumed (in accordance with EPA guidance) that doses would accumulate in the body for a total of 50 years after the accident (DIRS 101069-Eckerman et al. 1988, p. 7). For external exposures (from ground contamination and contaminated food consumption), the analysis assumed an exposure period of 30 days (DIRS 182588-NRC 2007, p. 4). It was also assumed that the accident occurred during the fall of the year so that the 30-day exposure period included harvesting and consumption of contaminated food crops.

The analysis used the projected population around the repository in 2067 (Chapter 3, Figure 3-15). The exposed population would be individuals living within about 80 kilometers (50 miles) of the repository, including pockets of people who would reside just beyond the 80-kilometer distance. DOE selected the south-southeast sector to compute population doses because this sector would contain the highest population out to 80 kilometers (Chapter 3, Figure 3-16) and the predominant wind direction is very near to this direction (Chapter 3, Figure 3-3). The dose calculation used the specific dispersion factor (dilution of the plume with distance) for this sector (DIRS 104441-YMP 1998, all). The population dose calculations included impacts from the consumption of food that radionuclide releases contaminated. The contaminated food consumption analysis used site-specific data on food production and consumption for the region around the Yucca Mountain site (DIRS 177751-BSC 2007, Section 8.4).

DOE has not evaluated in detail the potential cleanup costs in relation to the accident scenarios, but the Yucca Mountain FEIS did consider the cleanup costs for transportation accidents that involved material en route to the repository (DIRS 155970-DOE 2002, Appendix J, Section J.1.4.2.5). Such costs are highly uncertain, and would depend on the types of soils and remediation actions and the extent of cleanup, which would be based on the requirements that existed at the time of the accident. As noted in the FEIS, the costs could range from about $1 million to $10 billion for severe, maximum reasonably foreseeable transportation accidents. For the repository accident scenarios, DOE expects costs to be below the lower end of this range because the releases would be very small and the land near the repository would be federally controlled, undeveloped, and uninhabited. In any event, liability for and recovery of costs of such accidents would be covered under provisions of the Price-Anderson Act (Section 170 of the *Atomic Energy Act*, as amended; 42 U.S.C. 2011 et seq.), which currently provides for costs as high as $10.26 billion, as described in Appendix H of this Repository SEIS.

E.4.2 CATEGORY 2 ACCIDENT SCENARIO CONSEQUENCES

To calculate the potential consequences for the Category 2 accident scenarios (Table E-1), the analysis did not take credit for mitigation measures (evacuation and interdiction of contaminated foods). This assumption ensured that the estimated consequences would be conservative. Tables E-11 and E-12 list the results of the consequence calculations. Table E-11 provides the consequence results for unfavorable (95th-percentile) weather conditions. Unfavorable weather conditions (those that could result in a high dose) would occur no more than 5 percent of the time. Table E-12 provides the consequence results for annual average weather (50th-percentile). These conditions would result in average doses. The tables list doses in millirem for individuals and in person-rem (collective dose to all exposed persons) for the 80-kilometer (50-mile) population around the site. For selected individuals and populations, the tables list

Table E-11. Estimated radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) sector-specific meteorological conditions.

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
1. Drop of, or equipment drop on, naval canister with breach	1.7×10^{-2} (3.4×10^{-4})	2.0×10^{-4} (4.6×10^{-2})[c]	1.2×10^{-7}	5.4×10^{0} (4.0×10^{2})[c]	3.2×10^{-3}	1.5×10^{-2} (5.6×10^{0})[c]	9.0×10^{-6}
2. Drop with breach of HLW canisters in transportation cask	2.1×10^{-2} (4.2×10^{-4})	2.4×10^{-5} (2.4×10^{-3})[c]	1.4×10^{-8}	2.0×10^{-1} (2.0×10^{1})[c]	1.2×10^{-4}	3.2×10^{-3} (3.2×10^{-1})[c]	1.9×10^{-6}
3. Drop of HLW in an unsealed waste package or drop of equipment on HLW with breach	9.8×10^{-2} (2.0×10^{-3})	2.4×10^{-4} (2.4×10^{-2})[c]	1.4×10^{-7}	2.0×10^{3} (2.0×10^{5})[c]	1.2×10^{-3}	3.2×10^{-2} (3.2×10^{4})[c]	2.0×10^{-5}
4. Drop with breach of HLW canister during transfer	2.1×10^{-1} (4.2×10^{-3})	9.6×10^{-5} (9.6×10^{-3})[c]	5.8×10^{-8}	8.0×10^{-1} (8.0×10^{1})[c]	4.8×10^{-4}	1.3×10^{-2} (1.3×10^{0})[c]	7.8×10^{-6}
5. Drop of transportation cask with breach of PWR assemblies	8.7×10^{-2} (1.7×10^{-3})	1.2×10^{-3}	7.2×10^{-7}	3.0×10^{-5}	1.8×10^{-2}	1.9×10^{-1}	1.1×10^{-4}
6. Drop of inner lid of transportation cask of PWR assemblies with breach in water	4.4×10^{-2} (8.8×10^{-4})	9.2×10^{-4}	5.5×10^{-7}	2.5×10^{1}	1.5×10^{-2}	5.2×10^{-2}	3.1×10^{-5}
7. Drop of, or drop of equipment on, DPC with breach	5.7×10^{-2} (1.1×10^{-3})	1.1×10^{-2}	6.6×10^{-6}	2.7×10^{2}	1.6×10^{-1}	1.7×10^{0}	1.0×10^{-3}
8. Drop of, or drop of equipment on, DPC with breach in water	2.1×10^{-2} (4.2×10^{-4})	8.2×10^{-3}	4.9×10^{-6}	2.3×10^{2}	1.4×10^{-1}	4.6×10^{-1}	2.8×10^{-4}
9. Drop with breach of TAD canister	5.0×10^{-1} (1.0×10^{-2})	6.4×10^{-3}	3.8×10^{-6}	1.6×10^{2}	9.6×10^{-2}	1.0×10^{0}	6.0×10^{-4}

Table E-11. Estimated radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) sector-specific meteorological conditions (continued).

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
10. Drop of lid into TAD canister in water with breach of fuel assemblies	1.7×10^{-2} (3.4×10^{-4})	4.8×10^{-3}	2.9×10^{-6}	1.3×10^{2}	7.8×10^{-2}	2.7×10^{-1}	1.6×10^{-4}
11. Drop with breach of fuel assembly in water	4.8×10^{-2} (9.6×10^{-3})	4.6×10^{-4}	2.7×10^{-7}	1.3×10^{1}	7.8×10^{-3}	2.6×10^{-2}	1.6×10^{-5}
12. Collision or drop of equipment on fuel assembly in water with breach	4.8×10^{-1} (9.6×10^{-3})	2.3×10^{-4}	1.4×10^{-7}	6.3×10^{0}	3.8×10^{-3}	1.3×10^{-2}	7.8×10^{-6}
13. Fire involving LLW	5.0×10^{-1} (1.0×10^{-2})	6.2×10^{-6}	3.7×10^{-9}	4.9×10^{-2}	2.9×10^{-5}	4.0×10^{-4}	2.4×10^{-7}
14. Seismic event involving failure of HEPA system and LLW confinement	$<1.0 \times 10^{-4}$ ($<2.0 \times 10^{-6}$)	2.3×10^{1}	1.4×10^{-8}	1.9×10^{2}	1.1×10^{-1}	2.3×10^{0}	1.4×10^{-3}

a. Assumed to be at the analyzed land withdrawal boundary either in the east sector (7.8 kilometers or 4.8 miles) or in the southeast sector (18.5 kilometers or 11 miles), whichever produces the highest site boundary dose. For accident scenarios 6, 8, 10, 11 and 12, DOE calculated the highest dose for the southeast sector. For all other accident scenarios, DOE calculated the highest dose for the east sector.

b. LCF_i is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose (rem). LCF_p is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose to LCFs as discussed in Section E.4.1.

c. Unfiltered doses presented to illustrate that filtration systems might not be required in the Initial Handling Facility to meet regulatory standards.

DPC = Dual-purpose canister.
HEPA = High-efficiency particulate air.
HLW = High-level radioactive waste.
LCF = Latent cancer fatality.
LLW = low-level radioactive waste.
PWR = Pressurized-water reactor.
TAD = Transportation, aging, and disposal (canister).

Table E-12. Estimated radiological consequences of repository operations accident scenarios for annual average (50th-percentile) sector-specific meteorological conditions.

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
1. Drop of, or equipment drop on, naval canister with breach	1.7×10^{-2} (3.4×10^{-4})	3.1×10^{-6}	1.9×10^{-9}	3.6×10^{-2}	2.2×10^{-5}	2.4×10^{-3}	1.4×10^{-6}
2. Drop with breach of HLW canisters in transportation cask	2.1×10^{-2} (4.2×10^{-4})	4.1×10^{-7}	2.5×10^{-10}	1.4×10^{-3}	8.4×10^{-7}	5.3×10^{-4}	3.2×10^{-7}
3. Drop of HLW canisters in an unsealed waste package or drop of equipment on HLW canisters with breach	9.8×10^{-2} (2.0×10^{-3})	4.1×10^{-6}	2.5×10^{-9}	1.4×10^{-2}	8.4×10^{-6}	5.3×10^{-3}	3.2×10^{-6}
4. Drop with breach of HLW canisters during transfer	2.1×10^{-1} (4.2×10^{-3})	1.6×10^{-6}	9.6×10^{-10}	5.6×10^{-3}	3.4×10^{-6}	2.1×10^{-3}	1.3×10^{-6}
5. Drop of transportation cask with breach of PWR assemblies	8.7×10^{-2} (1.7×10^{-3})	7.2×10^{-5}	4.3×10^{-8}	5.6×10^{-1}	3.4×10^{-4}	8.3×10^{-2}	5.0×10^{-5}
6. Drop of inner lid of transportation cask of PWR assemblies with breach in water	4.4×10^{-2} (8.8×10^{-4})	1.1×10^{-5}	6.6×10^{-9}	1.5×10^{-1}	9.0×10^{-5}	8.4×10^{-3}	5.0×10^{-6}
7. Drop of, or drop of equipment on, DPC with breach	5.7×10^{-2} (1.1×10^{-3})	6.5×10^{-4}	3.9×10^{-7}	5.0×10^{0}	3.0×10^{-3}	7.5×10^{-1}	4.5×10^{-4}
8. Drop of, or drop of equipment on, DPC with breach in water	2.1×10^{-2} (4.2×10^{-4})	1.0×10^{-4}	6.0×10^{-8}	1.4×10^{0}	8.4×10^{-4}	7.6×10^{-2}	4.6×10^{-5}
9. Drop with breach of TAD canister	5.0×10^{-1} (1.0×10^{-2})	3.8×10^{-4}	2.3×10^{-7}	2.9×10^{0}	1.7×10^{-3}	4.4×10^{-1}	2.6×10^{-4}

Table E-12. Estimated radiological consequences of repository operations accident scenarios for annual average (50th-percentile) sector-specific meteorological conditions (continued).

Accident scenario	Expected occurrences over the preclosure period (annual frequency)	Maximally exposed offsite individual[a]		Population		Noninvolved worker	
		Dose (rem)	LCF_i[b]	Dose (person-rem)	LCF_p[b]	Dose (rem)	LCF_i[b]
10. Drop of lid into TAD canister in water with breach of fuel assemblies	1.7×10^{-2} (3.4×10^{-4})	5.9×10^{-5}	3.5×10^{-8}	7.7×10^{-1}	4.8×10^{-4}	4.4×10^{-2}	2.6×10^{-5}
11. Drop with breach of fuel assembly in water	4.8×10^{-2} (9.6×10^{-3})	5.6×10^{-6}	3.4×10^{-9}	7.4×10^{-2}	4.4×10^{-5}	4.2×10^{-3}	2.5×10^{-6}
12. Collision or drop of equipment on fuel assembly in water with breach	4.8×10^{-2} (9.6×10^{-3})	2.8×10^{-6}	1.7×10^{-9}	3.7×10^{-2}	2.3×10^{-5}	2.1×10^{-3}	1.3×10^{-6}
13. Fire involving LLW	5.0×10^{-1} (1.0×10^{-2})	1.2×10^{-7}	7.2×10^{-11}	4.4×10^{-4}	2.6×10^{-7}	6.6×10^{-5}	4.0×10^{-8}
14. Seismic event involving failure of HEPA system and LLW confinement	$<1.0 \times 10^{-4}$ ($<2.0 \times 10^{-6}$)	4.4×10^{-4}	2.6×10^{-7}	1.6×10^{0}	9.6×10^{-4}	3.7×10^{-1}	2.2×10^{-4}

a. Assumed to be at the analyzed land withdrawal boundary in the east sector, which would produce the highest site boundary dose at a distance of 7.8 kilometers (4.8 miles).

b. LCF_i is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose (rem). LCF_p is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose to LCFs as discussed in Section E.4.1.

DPC = Dual-purpose canister.
HEPA = high-efficiency particulate air.
HLW = High-level radioactive waste.
LCF = Latent cancer fatality.
LLW = low-level radioactive waste.
PWR = Pressurized-water reactor.
TAD = Transportation, aging, and disposal (canister).

estimated probability and number of latent cancer fatalities for the maximally exposed offsite individual, the public, and noninvolved workers over the lifetimes of the exposed individuals as a result of the calculated doses using the conversion factors in Section E.4.1. These estimates do not consider the accident frequency. The accident scenario with the highest population impact for the unfavorable weather conditions (seismic event involving failure of high-efficiency particulate air system and low-level radioactive waste confinement) would result in an estimated 0.11 latent cancer fatality for this same population.

Radiological dose information is also provided in Table E-11 for accidents in the Initial Handling Facility that do not credit the filtration system. As indicated previously, these results are only provided to illustrate that these filtration systems may not be required to meet regulatory standards, however, since they are an integral part of the current facility design, this SEIS does credit the filters in the analysis of impacts. The estimated annual frequencies of these events are consistent with the availability of the filters.

E.5 Monitoring and Closure Accident Scenarios

During monitoring and closure activities, DOE would not move the waste packages, with the possible exception of removal of a container from an emplacement drift for examination or drift maintenance. No additional accident scenarios unique to monitoring or closure were identified.

E.6 Inventory Modules 1 and 2 Accident Scenarios

Inventory Modules 1 and 2 are alternative inventory options that this Repository SEIS considers for potential cumulative impacts in Chapter 8. These modules would involve additional waste material for emplacement in the repository. They would involve the same types of waste and handling activities as those for the Proposed Action, but the quantity of materials DOE would receive would increase, as would the period of emplacement operations. The analysis assumed the receipt and emplacement rates would remain the same as those for the Proposed Action. Therefore, the estimated consequences of the accident scenarios for operations would encompass the potential consequences of an accident in relation to Inventory Modules 1 and 2 because the same set of operations would be involved.

E.7 Representative Sabotage Scenario

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the United States Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements to prevent terrorists from gaining control of commercial aircraft, such as (1) more stringent screening of airline passengers and baggage by the Transportation Security Administration, (2) increased presence of Federal Air Marshals on many flights, (3) improved training of flight crews, and (4) hardening of aircraft cockpits. Additional measures have been imposed on foreign passenger carriers and domestic and foreign cargo carriers, as well as charter aircraft.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities.

The use of robust metal waste packages to contain the spent nuclear fuel and high-level waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (before closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

NRC regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level radioactive waste do not constitute an unreasonable risk to public health and safety." The regulations require the storage of spent nuclear fuel and high-level radioactive waste in a protected area such that:

- Access to the material would require passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

NRC regulations would require a trained, equipped, and qualified security force to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. NRC requires liaison with response forces to permit timely response to unauthorized entry or activities. In addition, the NRC requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location sufficiently remote from the original records that a single event would not destroy both sets of records.

Although it is difficult to predict if sabotage events would occur, and the nature of such events if they were to occur, in response to public comments and to evaluate a scenario that would approximate the consequences of a major sabotage event, DOE analyzed a hypothetical scenario in which a large commercial jet aircraft would crash into and penetrate the repository facility with the largest inventory of radioactive material vulnerable to damage from such an event. Table E-13 lists the potentially affected amounts of radiological materials in major surface buildings. The aging pads could contain a large amount of commercial spent nuclear fuel, but DOE did not consider this location to be vulnerable to the aircraft crash scenario because (1) the storage modules on the aging pads would be separated by 5.5 meters (18 feet) (DIRS 180195-BSC 2007, all) such that an aircraft crash into the pad could not damage more than a few of the modules, and (2) the storage canisters will be enclosed in thick concrete overpacks that would provide protection from penetration by aircraft parts (DIRS 155970-DOE 2002, Appendix H, p. H-37 and Chapter 7, p. 7-30).

Table E-13. Materials at risk for aircraft crash scenario.

	Commercial SNF assemblies					
	PWR	BWR	Naval SNF		HLW	DOE SNF
Initial Handling Facility			1 canister	or	5 canisters	
Canister Receipt and Closure Facility	42[a]					9 canisters
Receipt Facility	36[b]					
Wet Handling Facility	80[c]	120[c]				
	36[d] or	74[d]				

Source: DIRS 182084-Wisenburg 2007, all.

a. Based on 2 TAD canisters with 21 PWR assemblies each.

b. Based on 1 DPC canister with 36 PWR assemblies.

c. These assemblies would be in the Wet Handling Facility pool.

d. These assemblies would be in the loading process (under water) from a DPC into a TAD canister.

BWR = Boiling-water reactor.
DOE = U.S. Department of Energy
DPC = Dual-purpose canister.
HLW = High-level radioactive waste.
PWR = Pressurized-water reactor.
SNF = Spent nuclear fuel.
TAD = Transportation, aging, and disposal (canister).

As shown in the table, the Wet Handling Facility would contain the most material. However, most of the fuel assemblies would be underwater in the below-ground storage pool. Similar to the conclusion in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Appendix H, p. H-38), fuel in this pool would not be vulnerable to an aircraft crash because the pool water would limit the potential for a fire to affect the fuel directly and would limit the release from damaged fuel assemblies. The next largest number of fuel assemblies from Table E-13 is 42 pressurized-water reactor fuel assemblies in a Canister Receipt and Closure Facility. As the table indicates, nine canisters of DOE spent nuclear fuel could be in the Canister Receipt and Closure Facility at the same time. However, the analysis did not consider the DOE spent nuclear fuel inventory for the sabotage consequence calculation because these canisters will remain sealed while in the Canister Receipt and Closure Facility. Further, DOE spent nuclear fuel canisters will be designed to preclude a breach if dropped during handling operations (Section E.2.1.1). The canisters will be robust steel containers not expected to breach during the aircraft crash event. There could be as many as four TAD canisters in the Canister Receipt and Closure Facility at a given time (DIRS 182084-Wisenburg 2007, all). However, at least two of these canisters are expected to be in either a transportation cask awaiting removal or a sealed waste package awaiting transfer to the emplacement drifts (Chapter 2, Section 2.1.2.1.3). These TAD canisters are expected to be protected from the aircraft impact because of the thick steel walls of the transportation cask and waste package.

For the representative scenario, DOE assumed the aircraft penetrated the roof of the building and the aircraft parts and debris from the roof impact would breach the two TAD canisters and rupture 100 percent of the fuel rods within the canisters. The fuel aboard the aircraft is conservatively assumed to catch fire and heat and oxidize all the commercial spent nuclear fuel assembly pellets in the 42 fuel assemblies into powder form. The radionuclide release from the scenario would result from two sources: (1) mechanical damage to the fuel assemblies that would rupture the Zircaloy cladding, release activity in the gap, and pulverize a portion of the fuel pellets into particles (some of which would be small enough to be transported to the nearest receptor and be inhaled) and (2) the large fire from the jet fuel. DOE conservatively assumed that the fire would convert all of the fuel in the two TAD canisters (a total of 42 assemblies from pressurized-water reactor spent nuclear fuel) from uranium dioxide (UO_2) to uranium trioxide (U_3O_8) and produce a powder that contained radionuclides. Because all of the fuel pellet material in the 42 pressurized-water reactor fuel assemblies would become powder, the particulates from the mechanical damage would not contribute further to the source term. The analysis assumed that 12 percent of the uranium trioxide particles would become airborne and 1 percent of the airborne particles would be respirable (small enough for downwind receptors to inhale into the lungs) (DIRS 155970-DOE 2002, Appendix H, p. H-38) Therefore, the analysis assumed that the fuel pellet respirable particulate source term would be 0.12 percent of the radionuclides in the 42 fuel assemblies. DOE assumed that the release would occur at ground level. This is conservative because the fire from the aircraft fuel would tend to loft the plume containing the radionuclides. This would result in increased plume dispersion and lower downwind radionuclide concentrations. For the radionuclides in gas form (chlorine, hydrogen, iodine, krypton, and carbon), the respirable fraction is 1.0. The radionuclide inventory in the assemblies was assumed to be the representative fuel (DIRS 180185-BSC 2007, all). This fuel would have a burnup of 50 gigawatt-days per metric ton of uranium and a cooling time of 10 years. It would not be realistic to assume that the fuel in the Canister Receipt and Closure Facility for this scenario would be the same as the maximum fuel (Section E.3.3) for the accident scenarios. The representative fuel represents a conservative estimate of the characteristics of the large number of commercial spent nuclear fuel assemblies that would be in a Canister Receipt and Closure Facility at any given time during the year (DIRS 180185-BSC 2007, all). The crud source term includes 209 curies of iron-55 and 16.9 curies of cobalt-60 per assembly (DIRS 180185-BSC 2007, all). Consistent with the FEIS analysis (DIRS 155970-DOE 2002, Appendix H, p. H-38), all of the iron and cobalt would be released because the Zircaloy cladding would burn during the accident. The respirable airborne release fraction for the radionuclides in the crud would be 0.05 (DIRS 103711-Davis et al. 1998, all). Table E-14 provides the source term for the aircraft crash scenario.

The analysis used the GENII program to calculate the consequences from the crash with the assumptions in Section E.4.1, except that for this case, due to the large release and potential for large doses, the analysis did assume mitigation would occur. Mitigation measures would include evacuation of affected population after 24 hours and interdiction of contaminated crops so that consumption of contaminated food would not occur. Table E-15 lists the results of the consequence evaluation for the scenario for annual average weather conditions. The Repository SEIS analysis assumed that the wind would blow to the south-southeast and expose the entire population in this sector (104,000 persons).

Table E-14. Source term (curies) for the aircraft crash scenario.

Radionuclide	Per PWR assembly	Per 42 assemblies	Respirable airborne release
Americium-241	1.2×10^{3}	5.0×10^{4}	6.0×10^{1}
Americium-242	7.2×10^{0}	3.0×10^{2}	3.6×10^{-1}
Americium-242m	7.2×10^{0}	3.0×10^{2}	3.6×10^{-1}
Americium-243	3.5×10^{1}	1.5×10^{3}	1.8×10^{0}
Barium-137m	6.1×10^{4}	2.6×10^{6}	3.1×10^{3}
Carbon-14	4.0×10^{-1}	1.7×10^{1}	1.7×10^{1}
Cadmium-113m	2.1×10^{1}	9.0×10^{2}	$1.8 x 10^{0}$
Chlorine-36	8.0×10^{-3}	3.4×10^{-1}	3.4×10^{-1}
Curium-242	5.9×10^{0}	2.5×10^{2}	3.0×10^{-1}
Curium-243	2.2×10^{1}	9.2×10^{2}	1.1×10^{0}
Curium-244	5.3×10^{3}	2.2×10^{5}	$2.7 x 10^{2}$
Curium-245	7.3×10^{-1}	3.1×10^{1}	3.7×10^{-2}
Curium-246	3.7×10^{-1}	1.6×10^{1}	1.9×10^{-2}
Cobalt-60	1.7×10^{1}	7.1×10^{2}	8.4×10^{-1}
Cesium-134	4.9×10^{3}	2.1×10^{5}	2.5×10^{2}
Cesium-135	3.4×10^{-1}	1.4×10^{1}	1.7×10^{-2}
Cesium-137	6.4×10^{4}	2.7×10^{6}	3.2×10^{3}
Europium-154	2.7×10^{3}	1.1×10^{5}	1.4×10^{2}
Europium-155	5.8×10^{2}	2.4×10^{4}	2.9×10^{1}
Iron-55	2.1×10^{2}	8.8×10^{3}	1.1×10^{1}
Hydrogen-3	2.8×10^{2}	1.2×10^{4}	1.2×10^{4}
Iodine-129	3.0×10^{-2}	1.3×10^{0}	1.3×10^{0}
Krypton-85	3.1×10^{3}	1.3×10^{5}	1.3×10^{5}
Niobium-93m	2.3×10^{1}	9.7×10^{2}	1.1×10^{0}
Niobium-94	8.1×10^{-1}	3.4×10^{1}	4.1×10^{-2}
Nickel-59	1.7×10^{0}	7.1×10^{1}	8.5×10^{-2}
Nickel-63	2.4×10^{2}	1.0×10^{4}	1.2×10^{1}
Neptunium-237	2.6×10^{-1}	1.1×10^{1}	1.3×10^{-2}
Protactinium-231	1.6×10^{-5}	6.7×10^{-4}	8.0×10^{-7}
Palladium-107	1.1×10^{-1}	4.6×10^{0}	5.5×10^{-3}
Promethium-147	5.5×10^{3}	2.3×10^{5}	2.8×10^{2}
Plutonium-238	3.6×10^{3}	1.5×10^{5}	1.8×10^{2}
Plutonium-239	1.6×10^{2}	6.7×10^{3}	7.8×10^{-1}
Plutonium-240	3.3×10^{2}	1.4×10^{4}	1.7×10^{1}
Plutonium-241	5.1×10^{4}	2.1×10^{6}	2.6×10^{3}
Plutonium-242	2.2×10^{0}	9.2×10^{1}	1.1×10^{-1}
Ruthenium-106	3.6×10^{2}	1.5×10^{4}	1.8×10^{1}
Antimony-125	4.7×10^{2}	2.0×10^{4}	2.4×10^{1}
Selenium-79	5.0×10^{-2}	2.1×10^{0}	2.5×10^{-3}
Samarium-151	2.3×10^{2}	9.7×10^{3}	1.1×10^{1}
Tin-126	4.6×10^{-1}	1.9×10^{1}	2.3×10^{-2}
Strontium-90	4.1×10^{4}	1.7×10^{6}	2.0×10^{3}
Technetium-99	9.6×10^{0}	4.0×10^{2}	4.9×10^{-1}
Thorium-230	5.5×10^{-5}	2.3×10^{-3}	2.8×10^{-6}
Uranium-232	3.3×10^{-2}	1.4×10^{0}	1.7×10^{-3}
Uranium-233	2.3×10^{-5}	9.7×10^{-4}	1.1×10^{-6}
Uranium-234	4.7×10^{-1}	2.0×10^{1}	2.3×10^{-2}
Uranium-235	3.8×10^{-3}	1.6×10^{-1}	$1.9 \times 10^{--4}$
Uranium-236	1.6×10^{-1}	6.7×10^{0}	8.0×10^{-3}
Uranium-238	1.3×10^{-1}	5.5×10^{0}	6.6×10^{-3}
Yttrium-90	4.1×10^{4}	1.7×10^{6}	2.0×10^{3}
Zirconium-93	9.4×10^{-1}	3.9×10^{1}	$4.7 \times 10^{—2}$

PWR = Pressurized-water reactor.

Table E-15. Estimated doses and latent cancer fatality estimates for aircraft crash scenario.

Receptor	Dose	Latent cancer fatalities
Maximally exposed offsite individual	4.0 rem	2.4×10^{-3}[(a)]
80-kilometer (50-mile) population	1.3×10^{4} person-rem	7.8[b]

a. Estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose.
b. Estimated number of cancers in the exposed population from the collective population dose.

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Appendix F

Environmental Impacts of Postclosure Repository Performance

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F. ENVIRONMENTAL IMPACTS OF POSTCLOSURE REPOSITORY PERFORMANCE

This appendix provides detailed information on the calculation of the environmental impacts of the postclosure period of repository performance. Chapter 5 of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) summarizes these impacts for the Proposed Action. This appendix summarizes, incorporates by reference, and updates Appendix I of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, pp. I-1 to I-94) (Yucca Mountain FEIS). Since completion of the FEIS, DOE has modified the Total System Performance Assessment (TSPA) model it uses to assess long-term repository performance to account for design, data, model, and analysis changes since 2002. For this Repository SEIS, DOE based the analysis on *Total System Performance Assessment Model /Analysis for the SEIS* (DIRS 182846-SNL 2007, all) (TSPA-SEIS).

Section F.1 introduces the bases for analysis of postclosure performance. Section F.2 provides an overview of the use of computational models the U.S. Department of Energy (DOE or the Department) developed for the TSPA-SEIS model it used for the analysis of postclosure performance in this Repository SEIS. Section F.3 identifies and quantifies the inventory of waste constituents of concern for analysis of postclosure performance. Section F.4 describes an estimate of how the impacts could change for locations beyond the location of the reasonably maximally exposed individual (RMEI). Section F.5 provides detailed results for waterborne radioactive material impacts, and Section F.6 provides the same for waterborne chemically toxic material impacts.

F.1 Introduction

The model that DOE used to evaluate postclosure impacts of radioactive materials in the groundwater simulates the release and transport of radionuclides away from the proposed repository into the unsaturated zone, through the unsaturated zone, and ultimately through the saturated zone to the accessible environment. Analysis of postclosure performance depended on the underlying process models necessary to provide thermal-hydrologic conditions, near-field geochemical conditions, degradation characteristics of the engineered barrier system, and unsaturated and saturated zone flow fields as a function of time. The use of these underlying process models involved multiple sequential steps before modeling of the overall system could begin.

Figure F-1 shows the general flow of information between data sources, process models, and the TSPA-SEIS model. The figure identifies several process-level computer models (for example, the site- and drift-scale thermal hydrology model and the saturated zone flow and transport model). The process models are large complex computer programs that DOE used in detailed studies to provide information to the TSPA-SEIS model. These process models are based on fundamental laboratory and field data DOE introduced into the modeling. The subsystem and abstracted models section of the figure encompasses those portions of the TSPA-SEIS model that the GoldSim program models (for example, the unsaturated zone flow fields and the biosphere dose conversion factors). These models are generally much simpler than the process models. They represent the results of the more detailed process modeling studies. They often are simple functions or tables of numbers. This process is called abstraction. It is necessary for

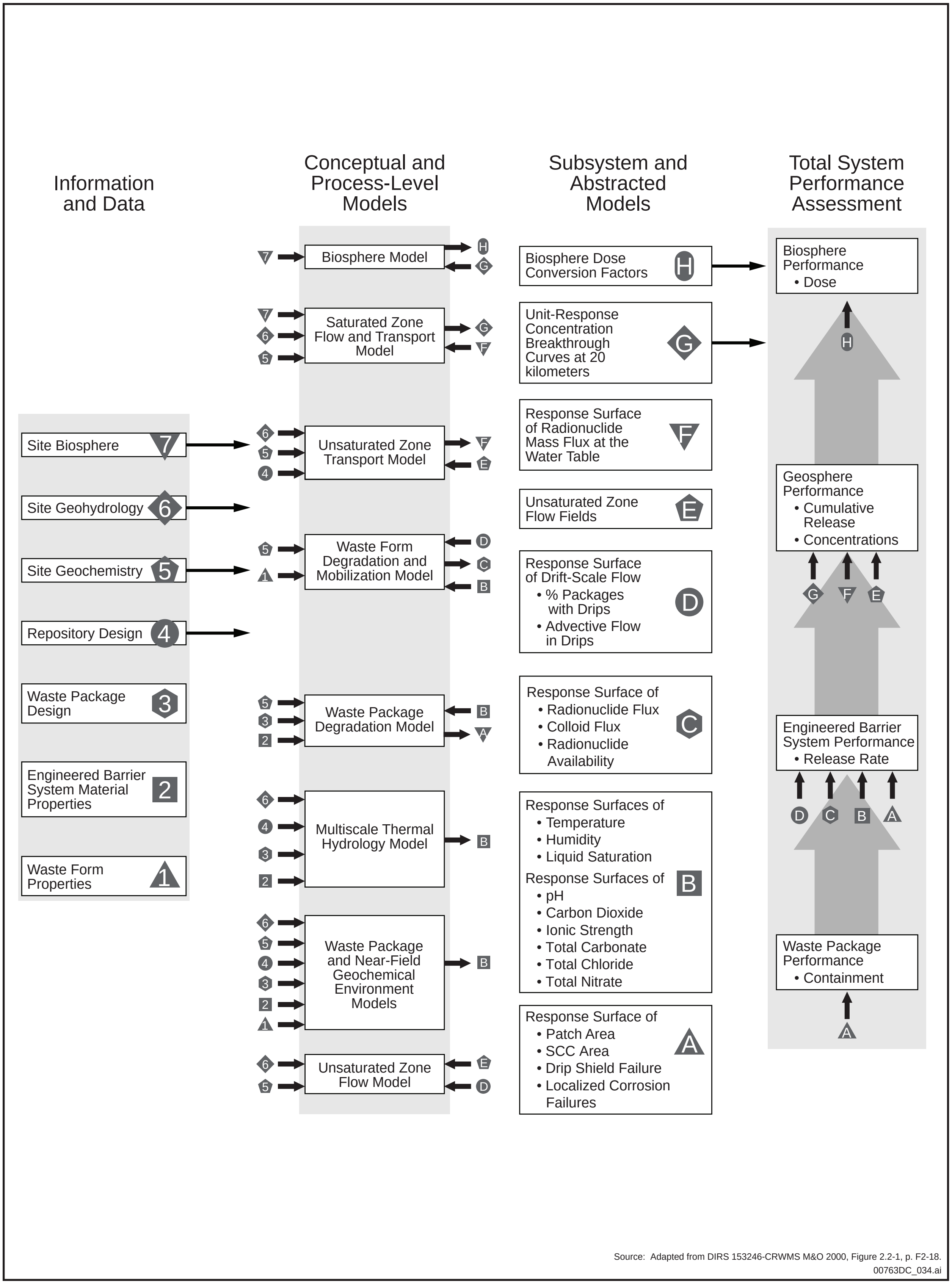

Figure F-1. Information flow in the TSPA-SEIS model.

some of these subsystem models to be complex, even extensive computer programs. The result that DOE sought from modeling postclosure performance was a characterization of radiological dose to humans in relation to time (at the top of the TSPA section of Figure F-1). The model accomplished this by an assessment of behavior at intermediate points and "handing off" the results to the next subsystem in the primary release path.

ABSTRACTION

Abstraction is the distillation of the essential components of a process model into a suitable form for use in a total system performance assessment. The distillation must retain the basic intrinsic form of the process model but does not usually require its original complexity. Model abstraction is usually necessary to maximize the use of limited computational resources while maintaining the relevant aspects of features, processes, and events that can affect postclosure performance.

F.2 Total System Performance Assessment Methods and Models

DOE conducted analyses for this Repository SEIS to evaluate potential postclosure impacts to human health from the release of radioactive materials from the proposed repository. The TSPA-SEIS model started with the model in the Yucca Mountain FEIS and includes several enhancements. Table 5-1 in Chapter 5 summarizes these enhancements.

The TSPA is a comprehensive systems analysis in which models of appropriate levels of complexity represent all important features, events, and processes to predict the behavior of the system under analysis and to compare this behavior to specified performance standards. In the case of the Yucca Mountain Repository system, a TSPA must capture the important components of both the engineered and the natural barriers. In addition, it must evaluate the overall uncertainty in the prediction of waste containment and isolation, and the risks such uncertainties cause in the individual component models and corresponding parameters.

The components of the Yucca Mountain repository system would include six major elements that the TSPA model has evaluated:

- Water flow from the ground surface through the unsaturated tuffs above and below the repository horizon, which would include water that dripped into the waste emplacement drifts;
- Thermal and chemical environments in the engineered barrier system, effects of disruptive events on that system, and perturbations to the surrounding natural system due to waste emplacement;
- The degradation of the engineered components that would contain the radioactive wastes;
- The release of radionuclides from the engineered barrier system;
- The migration of these radionuclides through the engineered and natural barriers to the biosphere and their potential uptake by people, which would lead to a radiation dose consequence; and
- The analysis includes models for disruptive events such as igneous activity, seismicity, and a hypothetical human intrusion (drilling).

This Repository SEIS analysis represents a snapshot in time of postclosure performance, and ongoing work will refine that snapshot.

The analysis for this Repository SEIS used a probabilistic framework for calculations that combined the most likely ranges of behavior for the component models, processes, and related parameters. In some cases, the analysis used bounding conservative values if the available data did not support development of a realistic range. This appendix presents the results as projections over time of annual radiological dose to an individual for the first 10,000 and the post-10,000-year period (up to 1 million years after repository closure). As noted in Section F.1, the TSPA-SEIS model provides a framework for incorporation of information from process models and abstraction models into an integrated representation of the repository system. This integration occurred in a Monte Carlo simulation-based method to create multiple random combinations of the likely ranges of the parameter values for the process models. The model computed the probabilistic performance of the entire waste disposal system in terms of radiological doses to the RMEI at a distance of approximately 18 kilometers (11 miles) south of the repository (the predominant direction of groundwater flow).

MONTE CARLO METHOD: UNCERTAINTY

Monte Carlo is an analytical method that uses random sampling of parameter values available for input into numerical models as a means to approximate the uncertainty in the process being modeled. A Monte Carlo simulation consists of many individual runs of the complete calculation, which uses different values for the parameters of interest sampled from a probability distribution. A different outcome for each calculation and each run of the calculation is called a realization.

F.2.1 FEATURES, EVENTS, AND PROCESSES

The first step in a TSPA is to determine the representations of possible future states of the proposed repository (scenarios and scenario classes). A scenario is a well-defined, connected sequence of events and processes that describes a possible future state of the repository system. A scenario class is a set of related scenarios that share sufficient similarities that they can usefully be aggregated for the purposes of screening or analysis. The objective of scenario analysis for the TSPA-SEIS is to define a set of scenario classes that can be quantitatively analyzed while maintaining comprehensive coverage of the range of possible future states of the repository system.

The first step in the development of scenario classes is to make an exhaustive list of the features, events, and processes that could apply to the repository system. Development of the initial list used a number of resources:

- Lists from other organizations on an international scale (such as the Nuclear Energy Agency of the Organization for Economic Cooperation and Development),
- Lists from earlier stages of site characterization, and
- Lists from experts from the Yucca Mountain Project and outside consultants.

The analysis subjected the starting list to a comprehensive screening process. It used the following criteria to screen features, events, and processes from the list:

- Inapplicability to the specific site (for example, the starting list included processes that occur only in salt, which is not present at Yucca Mountain),
- Very low probability of occurrence (for example, meteorite impact),
- Very low consequence to the closed repository (for example, an airplane crash), and
- Exclusion by regulatory direction (for example, deliberate human intrusion).

The analysis combined the remaining features, events, and processes in scenario classes that incorporate sequences of events and processes in the presence of features. The four main scenario classes are:

- Nominal Scenario Class (generally undisturbed performance)
- Early Failure Scenario Class (failure of drip shields and waste packages caused by manufacturing defects)
- Igneous Scenario Class (events and processes initiated by eruption through the repository or intrusion of igneous material into the repository)
- Seismic Scenario Class (events and processes initiated by ground motion or fault displacement)

In addition, the analysis evaluated a stylized, inadvertent Human Intrusion Scenario.

When DOE formed the scenario classes listed above from the features, events, and processes retained after screening, its focus was on the 10,000-year compliance period. The proposed Environmental Protection Agency and Nuclear Regulatory Commission standards specify that features, events, and processes excluded from the TSPA for the 10,000 year period after disposal may be excluded from the TSPA for the additional compliance period of geologic stability after 10,000 years, with the exception of features, events, and processes that relate to specific effects of seismicity, igneous activity, general corrosion, and climate change. The proposed standards also specify a value to be used to represent climate change after 10,000 years. Therefore, the SEIS analysis and projections of repository performance include the combined effects of seismicity (F.2.11), igneous activity (F.2.10), general corrosion (Section F.2.4), and the prescribed representation of climate change (Section F.2.2). In the Yucca Mountain FEIS, general corrosion and climate change were included. Igneous activity was not included directly in the combined calculation of repository performance, but was analyzed separately to estimate potential impacts from igneous activity alone. The FEIS analysis did include seismic activity and its effects on repository performance; however, processes representing seismic damage to waste packages were screened out for the 10,000 year period after disposal. The FEIS analysis for the post-10,000-year period extended the screening of seismic damage to waste packages throughout that time. This was an analytical assumption based on using the best data and models available for the FEIS. No quantitative analysis was performed to determine when a waste package might degrade to the point where it could be damaged by a seismic event.

In the SEIS, the mechanical response of engineered barrier system components to seismic hazards was included in the TSPA-SEIS analysis of potential seismic events for the 10,000-year period after disposal and the period of geologic stability. The seismic hazards addressed included vibratory ground motion, fault displacement, and drift collapse due to ground motion. The major engineered barrier system components considered in this analysis were the drip shield and the waste package because failure of these components could form advective and diffusive pathways that could result in the direct release of radionuclides from the engineered barrier system into the unsaturated zone. The drift invert and emplacement pallet were included in the structural response analyses for the engineered barrier system; however, it was not necessary to develop damage models for these components because they could not form new pathways for transport and release of radionuclides after seismic events. The waste package internals and the waste form were also considered in structural response analyses. However, in the SEIS, credit was not taken for the fuel rod cladding as a barrier to radionuclide release, so it was not necessary to include cladding damage due to a seismic event.

The following discussions provide a description of each seismic-related feature, event, and process that was included in the SEIS followed by a brief description of how that feature, event, and process was included in the TSPA-SEIS model.

FEP No. 1.2.03.02.0A: Seismic ground motion damages EBS components

Seismic activity that causes repeated vibration of the EBS components (drip shield, waste package, pallet, and invert) could result in disruption of the drip shields and waste packages, through vibration damage or through contact between EBS components. Such damage mechanisms could lead to degraded performance.

Structural calculations were used to simulate the response of the drip shield and waste package to vibratory ground motion. These calculations utilized a three-dimensional, dynamic structural analysis model that incorporated the details of the engineered barrier system design. Ground motion time histories input into the calculations represented postclosure hazard levels at the emplacement depth. The potential for structural damage and for separation of the drip shields was examined. The potential damage to the waste package due to ground motion-induced interactions of the waste packages, the pallet, and the drip shield were examined. Using these analyses, surface area damage was determined for input to the damage abstractions for the drip shield and waste package. Results of these studies were used in creating damage abstractions that were implemented in the TSPA-SEIS model for the Seismic Scenario Class.

FEP No. 1.2.03.02.0D: Seismic-induced drift collapse alters in-drift thermohydrology

Seismic activity could produce jointed-rock motion and/or changes in rock stress leading to enhanced drift collapse and/or rubble infill throughout part or all of the drifts. Drift collapse could impact flow pathways and condensation within the EBS, mechanisms for water contact with EBS components, and thermal properties within the EBS.

The potential for drift collapse and (or) rubble infill associated with vibratory ground motion was assessed using detailed two- and three-dimensional tunnel stability models. Ground motion time histories input into the calculations represent postclosure hazard levels at the emplacement depth. Emplacement drift profiles and the porosity of rubble material in the drift following a seismic event were used as input to a series of thermal-hydrologic simulations for representative in-drift conditions. These simulations were used to develop thermal-hydrologic abstractions that were implemented in the TSPA-SEIS to account for the effect of drift collapse on thermal-hydrologic conditions in the drift for the Seismic Scenario Class.

FEP No. 1.2.03.02.0C Seismic-induced drift collapse damages EBS components
Seismic activity could produce jointed-rock motion and/or changes in rock stress leading to enhanced drift collapse that could impact drip shields, waste packages, or other EBS components. Possible effects include both dynamic and static loading.

Structural calculations were used to simulate the response of the drip shield and waste package to vibratory ground motion and drift collapse. These calculations were used to quantify drip shield damage in terms of fragility curves on the peak ground velocity value for a given seismic event and the thickness of the drip shield components at the time of the seismic event. The effects of drift collapse on waste packages were quantified in terms of damaged areas or puncture areas based on the peak ground velocity value for a given seismic event and the thickness of the waste package outer corrosion barrier at the time of the seismic event. The fragility curves and damage areas were used to develop drip shield and waste package damage abstractions that were implemented in the TSPA-SEIS model.

FEP No. 1.2.02.03.0A: Fault displacement damages EBS components
Movement of a fault that intersects drifts within the repository may cause the EBS components to experience related movement or displacement. Repository performance may be degraded by such occurrences as tilting of components, component-to-component contact, or drip shield separation. Fault displacement could cause a failure as significant as shearing of drip shields and waste packages by virtue of the relative offset across the fault, or as extreme as exhumation of the waste to the surface.

An analysis was performed that examined how fault displacement could contribute to mechanical disruption of the engineered barrier system. In this analysis, estimates of very low probability fault displacement were compared with the dimensions of the engineered barrier features. Potential damage to the engineered barrier system was conservatively estimated, and the results were used to create drip shield and waste package damage abstractions that were implemented in the TSPA-SEIS. The output of these abstractions is the number of drip shields and waste packages failed by fault displacement and the combined surface area from the waste packages that fail from fault displacement; affected drip shields were assumed to completely fail.

F.2.2 UNSATURATED ZONE FLOW

Changes in climate over time provide a range of conditions that determine how much water could fall on and infiltrate the surface of Yucca Mountain. Based on current scientific estimates, the current climate is the driest that the Yucca Mountain vicinity is ever likely to experience. The analysis assumed that all future climates would be similar to or wetter than current conditions. The climate model provided a forecast of future climates based on information about past climate patterns (DIRS 170002-BSC 2004, all). This is generally accepted as a valid approach because climate is cyclical and largely dependent on repeating patterns of the Earth's orbit and spin. The model represented future climate shifts as a series of instant changes. During the first 10,000 years, there would be three changes, in order of increasing wetness, from present-day (0 to 600 years) to monsoon (600 to 2,000 years) and then to glacial-transition climate (2,000 to 10,000 years). In its proposed changes to 10 CFR 63.342(c), the U.S. Nuclear Regulatory Commission (NRC) directed DOE to represent climate change after 10,000 years (the post-

10,000-year climate) with a constant value determined from a log-uniform probability distribution for deep percolation rates from 13 to 64 millimeters (0.5 to 2.5 inches) per year.

Precipitation that did not return to the atmosphere by evaporation or plant transpiration could enter the unsaturated zone flow system. A number of factors that relate to climate, such as an increase or decrease in vegetation on the ground surface, total precipitation, air temperature, and runoff, could affect water infiltration. The infiltration model used in the FEIS was completely revised for this SEIS. The purpose of the revision was to increase confidence in the results by improving the traceability, transparency, and reproducibility of the model development; the selection and qualification of inputs for calculations; and the determination of net infiltration maps and fluxes. The revised infiltration model used data from studies of surface infiltration in the Yucca Mountain region (DIRS 174294-SNL 2007, all). The model applied a water mass-balance approach to the near surface layer that is influenced by evapotranspiration. It used a representation of downward water flow whereby water moves from the top soil layer downward by sequentially filling each layer to "field capacity" before draining to the layer below. Water was removed from the "root zone" by evapotranspiration, which was represented using an empirical model based on reference evapotranspiration, transpiration coefficients, and moisture content in the root zone. Water was redistributed as surface runoff when the soil could not accept all the available water at the surface. Precipitation was stochastically simulated on a daily time step based on observed weather records.

The results of the climate model affected infiltration rates. For each climate (present-day, monsoon, glacial transition, and post-10,000-year), there was a set of four infiltration rates (10th-, 30th-, 50th-, and 90th-percentile values) to represent uncertainty in infiltration rate. The corresponding weighting factors of 61.91, 15.68, 16.45, and 5.960 were used to describe the probability of occurrence for each of the four infiltration scenarios, and therefore, the sum of the four weighting factors is one. The same weighting factors were used in all four climate states of present-day, monsoon, glacial transition, and post 10,000 years.

Comparisons between unsaturated zone flow model simulations using the four infiltration scenarios and subsurface measured values of chloride and temperature data in combination with a likelihood uncertainty estimation methodology were used to determine the weighting factors; higher weights were given to infiltration maps that best match chloride and temperature data (DIRS 175177-SNL 2007, all). The infiltration rates and weighting factors form a discrete distribution that is sampled in the probabilistic modeling. The four infiltration cases represent *epistemic* uncertainty in the net infiltration rates. The TSPA-SEIS model sampled these infiltration cases once per realization (Table F-1) consistent with their weighting factors so that, for example, the 10th-percentile value was selected in approximately 62% of the realizations. Because of the once-per-realization sampling, the infiltration cases are completely correlated across the four climate states modeled for the simulation period (for example, during a realization in which the 50th-percentile infiltration case was sampled, that case would be used for each of the four climate states to select the appropriate unsaturated zone flow fields). This correlation of the infiltration uncertainty across the climate transitions ensures that the full effects of the infiltration uncertainty are not dampened out of the TSPA-SEIS model performance results.

The four post-10,000-year net infiltration rates presented in Table F-1 correspond to four infiltration maps that were developed to satisfy the log-uniform probability distribution for deep percolation rates from 13 to 64 millimeters (0.5 to 2.5 inches) per year, as the NRC directed. These four infiltration maps were developed by selecting, from the available 12 infiltration maps implemented for the first 10,000-year

Table F-1. Average net infiltration rates (millimeters per year) over the unsaturated zone flow and transport model domain for the present-day, monsoon, glacial transition, and post-10,000-year climate states.

Climate	Percentile			
	10th	30th	50th	90th
Present day	3.03	7.96	12.28	26.78
Monsoon	6.74	12.89	15.37	73.26
Glacial transition	11.03	20.45	25.99	46.68
Post-10,000-year	16.89	28.99	34.67	48.84
Weighting factor	61.91	15.68	16.45	5.960

Source: DIRS 175177-SNL 2007, all.

period after closure, the map that has an average infiltration rate through the repository footprint that most closely matches the required value (from the log-uniform probability distribution) for the post-10,000-year period (DIRS 175177-SNL 2007, all). Then all infiltration rates for that map are scaled such that the four target values for the average infiltration through the repository footprint are obtained to meet the NRC requirement. The resulting percolation fluxes through the repository footprint for the four post-10,000-year period average infiltration rates were, respectively, 21.58, 40.78, 52.07, and 61.86 millimeters per year.

Water generally moves downward in the rock matrix and in rock fractures. The rock mass at Yucca Mountain consists of volcanic rock with varying degrees of fracturing due to contraction during cooling of the original, nearly molten rock and because of extensive faulting in the area. Water flowing in the fractures moves much more rapidly than water moving through the rock matrix. At some locations, water can collect in locally saturated zones (perched water) or can be laterally diverted because of differing rock properties at rock layer interfaces.

The mountain-scale unsaturated zone flow model used constant flow during each climate state and generated three-dimensional flow fields for each of the four different infiltration boundary conditions (10th-, 30th-, 50th-, and 90th-percentile values) for each climate state and set of rock properties for each infiltration rate (DIRS 175177-SNL 2007, all). This is an isothermal model; thermal effects can be neglected because flow would be strongly perturbed only by heat near the emplacement drifts and during early times (DIRS 175177-SNL 2007, all). The thermal hydrology models discussed below deal with the influence of heat near the drifts. The flow fields from the mountain-scale unsaturated zone flow model are the abstractions the TSPA-SEIS model used while the system model was running. The TSPA-SEIS model simply switched to the flow field for the sampled infiltration rate and climate state.

After the repository cooled, water returned to the repository walls. However, because of a capillary barrier effect at the drift wall only a small fraction of this returned water dripped into the emplacement drifts. The remaining water was diverted around the emplacement drifts. The low rate at which water flows through Yucca Mountain, which is in a semiarid area, would restrict the number of seeps and the amount of water available to drip. Drips would occur only if the hydrologic properties of the rock mass caused the water to concentrate enough to feed a seep. Over time, the number and locations of seeps would tend to increase, corresponding to increasing infiltration due to changing climate conditions. The seepage flow model calculated the amount of seepage that could occur based from information from the unsaturated zone flow model (DIRS 177395-SNL 2007, all). The conceptual model for seepage has determined, based on direct field observations, that openings in unsaturated rock act as capillary barriers and divert water around them. For seepage to occur in the conceptual model, the rock pores at the drift wall would have to be locally saturated. Drift walls could become locally saturated by either disturbance to the flow field caused by the drift opening or variability in the permeability field that created channeled flow and local ponding. Of these two potential causes, the variability effect is more important. Drift-scale flow calculations made with uniform hydrologic properties suggested that seepage would not occur at expected percolation fluxes. However, calculations that included permeability variations do estimate seepage, with the amount dependent on the hydrologic properties and the incoming percolation flux. DOE based the seepage abstraction on extensive modeling calibrated by measurements from tests in the Exploratory Studies Facility (DIRS 181244-SNL 2007, all). The seepage abstraction included probability distributions for the fraction of waste packages that could encounter seepage and the seep flow rate; it accounted for parameter uncertainty, spatial variability, and other effects such as focusing, episodicity, rock bolts, drift degradation, and coupled processes (DIRS 177395-SNL 2007, all). All of these parameters were input as uncertainty distributions and sampled in the probabilistic TSPA-SEIS simulations.

F.2.3 ENGINEERED BARRIER SYSTEM ENVIRONMENTS

Engineered barrier system environments refer to the thermal-hydrologic and chemical environments in the emplacement drifts. These environments control processes that affect the engineered components of the system (such as the drip shields, waste packages, and waste forms). The environmental characteristics of importance are the degradation of the drift (which would include rock fall into the drift from seismic ground motion), temperature, relative humidity, liquid saturation, pH, liquid composition, and gas composition. Thermal effects on flow and chemistry outside the drifts would be important because they would affect the amount and composition of water and gas that entered the drifts. The engineered barrier system environments would be important to postclosure repository performance because they would help determine degradation rates of waste packages, degradation of waste forms in breached waste packages, quantities and species of mobilized radionuclides, transport of radionuclides from breached waste packages through the drift into the unsaturated zone, and movement of seepage water through the drift into the unsaturated zone.

Emplacement drifts could degrade with time as a result of seismic ground motion. These effects could lead to partial or complete drift collapse, with rock material filling the enlarged drifts and changing their shape and size. These effects could alter the thermal hydrology in the drifts and damage the engineered barriers. Depending on the intensity of these effects, impacts to thermal hydrology and damage to the engineered barriers and drifts could be small with local rock fall from the ceiling of otherwise intact drift openings or, in extreme cases, could result in substantial impacts to thermal hydrology and damage to the engineered barriers and partial or complete drift collapse, with rubble rock material filling the enlarged drifts (DIRS 176828-SNL 2007, all).

The TSPA-SEIS model performed most engineered system calculations for a limited number of waste package locations. In the model, each of these locations is representative of a group of waste packages with similar environmental characteristics. The model calculated radionuclide releases, for example, for representative codisposal and commercial spent nuclear fuel waste packages in each group and then scaled up by the number of failed waste packages of each type in each group. The waste package groups (referred to as percolation subregions) are not based on physical location but rather on percolation flux patterns (that is, divided into categories of specific ranges of percolation flux) (DIRS 177405-SNL 2007, all). The analysis defined five percolation subregions according to percolation-flux distributions.

The heat generated by the decay of nuclear materials in the proposed repository would cause the temperature of the surrounding rock and waste packages to rise from the time of emplacement until a few hundred years after repository closure (DIRS 177405-SNL 2007, all). The water and gas in the heated rock, referred to in this Repository SEIS as the thermal pulse, would be driven away from the repository during this period. The thermal output of the materials would decrease with time; eventually, the rock would return to its original temperature, and the water and gas would flow back toward the repository. DOE used the multiscale thermal hydrology model to study the processes that would govern the temperature, relative humidity, liquid saturation, liquid flow rate, liquid evaporation rate, and thermal effects on seepage. Drift-scale modeling included coupling of drift-scale processes with mountain-scale processes to account for effects such as faster cooling of waste packages near the edge of the repository in comparison to packages near the center. DOE developed a multiscale modeling and abstraction method to couple drift-scale processes with mountain-scale processes (DIRS 177405-SNL 2007, all). The analysis abstracted the results of detailed thermal-hydrologic modeling studies as response surfaces of temperature, humidity, and liquid saturation.

The source term for transport of radionuclides from the proposed repository through the unsaturated zone and saturated zone would be the radionuclide flux from inside the drifts to the unsaturated zone rock. The in-drift engineered barrier system chemical environment would influence that flux. DOE used the Physical and Chemical Environment Model (DIRS 177412-SNL 2007, all) to study the changing composition of gas, water, colloids, and solids in the emplacement drifts under the perturbed conditions of the repository. The analysis integrated several models to provide detailed results and interpretations. The thermal loading of the system would cause the major composition changes. Emplaced materials could be an additional source of colloids that could affect the transport of radionuclides in the aqueous system. The engineered barrier system chemical environment models produced detailed results that DOE abstracted for the following key processes:

- Chemistry of seepage water flowing into the drift. The composition of water that entered the repository drifts would have a primary influence on the types of brines that could form as evaporation occurred in the drifts. The composition of that water is closely coupled to the thermal-hydrologic processes in the host rock near the drifts. During the thermal period, water would boil and evaporate. Vapor would move away from the heated drifts, while condensed liquid water would simultaneously percolate down and replace the evaporated water. This process, which is referred to as “reflux,” would continue as long as the host rock was hot enough to support it. Percolating reflux waters would contain dissolved chemical species such as sodium, chlorides, calcium, and carbonates. If evaporation occurred, dissolved chemical species would precipitate as minerals and salts. After the primary thermal period passes, and after soluble precipitates and salts redissolved, the composition of seepage water that entered the drifts would approximate the composition of the pre-emplacement ambient percolation in the host rock.

- Composition of the gas phase in the emplacement drifts. The gas composition would influence the evolution of the chemical environment in the drifts. The gas composition would initially be similar to the composition of atmospheric air. However, during the thermal period, reactive components (oxygen and carbon dioxide) of the gas phase would be diluted by steam and strongly modified by water evaporation and interaction with carbon dioxide in water and carbonate minerals. One important aspect that affected the system would be the exsolution of carbon dioxide from the liquid phase as the temperature rose. This exsolution in the boiling zone in the rock would result in a localized increase in pH, which would decrease in the condensation zone where the vapor (enriched in carbon dioxide) was transported and condensed.

- Evolution of the chemical environment in the engineered barrier system. Seepage waters would enter drifts, either by dripping from the drift crown or by imbibition (the absorption of fluid by a solid body without resultant chemical change in either) into the invert. Once in the drifts, the chemical compositions of the seepage waters could change due to evaporation, mineral precipitation, or both. The composition of seepage water in the emplacement drift would change according to the sequence of minerals that precipitated from that solution as a function of the composition of seepage water in the drift, thermal conditions, relative humidity, and gas composition during evaporation. The chemistry of the water in the drift would affect the mobility of radionuclides in the engineered barrier system and the likelihood of initiation of localized corrosion if this water contacted waste packages.

DOE developed abstractions for the above chemical processes (DIRS 177412-SNL 2007, all) and integrated them in the TSPA-SEIS model as chemistry look-up tables.

Drift seepage is the flow of liquid water into emplacement drifts. Water that seeped into drifts could contact waste packages, mobilize radionuclides, and result in advective transport of radionuclides through waste packages breached by general corrosion and localized corrosion processes. The unsaturated rock layers that overlie and host the repository would form a natural barrier that reduced the amount of water that entered drifts by natural subsurface processes. For example, the capillary barrier would limit drift seepage at the drift crown, which would decrease or even eliminate water flow from the unsaturated fractured rock into the drift. During the first few hundred years after waste emplacement, when above-boiling rock temperatures would develop from the decay heat of the radioactive waste, vaporization of percolation water would further limit seepage. Estimating the effectiveness of these natural barrier capabilities and predicting the amount of seepage into drifts is an important aspect of assessing the performance of the repository. The TSPA-SEIS seepage abstraction model is based on a synthesis of detailed modeling studies (DIRS 177395-SNL 2007, all) and field testing (DIRS 177394-SNL 2007, all) that DOE abstracted as look-up tables for seepage into nondegraded and collapsed drifts as a function of capillary strength and tangential permeability of the fracture network near the drift wall.

Condensation water that dripped from drift walls would be another potential source of seepage water in the drift. The source of condensation water would be the invert and the drift wall. Natural convection would transport water vapor axially from hotter to cooler regions where the vapor could condense. The axial movement of the water vapor, the saturated vapor pressure at the drift wall and invert surface, and the change in temperature along the drifts would be the main factors that would drive the occurrence of condensation (DIRS 178868-SNL 2007, all).

Evaporation and mixing with condensation water and circulating gas, particularly during the thermal pulse, would strongly influence the chemistry of seepage water when it entered the drift. At later times, as the thermal pulse dissipated and condensation fluxes decreased, the chemistry of the seepage water would not change substantially from that when the water entered the drift.

The primary water input to the engineered barrier system would be the total flow rate from two sources: (1) the seepage volumetric flow rate into the drifts from the drift seepage abstraction model and (2) the condensation volumetric flow rate on the drift walls from the in-drift natural convection and condensation model. A secondary source of inflow to the engineered barrier system would be imbibition into the invert from the surrounding unsaturated rock matrix, from the Multiscale Thermohydrologic Model (DIRS 177405-SNL 2007, all).

The flow of water through the engineered barrier system could have eight pathways (DIRS 177407-SNL 2007, all):

- Seepage and drift wall condensation. This would be the water inflow from the crown (roof) of the drift. It would include drift seepage and any condensation on the section of the drift wall above the drip shield.

- Flow through the drip shields. DOE based the flow rate through the drip shields on the presence of breaches due to general corrosion (DIRS 180778-SNL 2007, all) or possible displacement of drip shields due to a seismic event (DIRS 176828-SNL 2007, all).

- Diversion around the drip shields. The portion of the dripping water that did not flow through the drip shield would flow directly to the invert.

- Flow through the waste packages. Three general types of openings in the waste packages could exist due to corrosion: (1) stress corrosion cracks from residual stress or seismic ground motion; (2) breaches from general corrosion; and (3) breaches from localized corrosion. DOE based the flow rate through the waste packages on the presence of breaches due to general and localized corrosion. Stress corrosion cracking could occur, but the analysis did not include the advective flow of water through stress corrosion cracks because (1) capillary behavior would allow water to reside indefinitely in the crack without flow; (2) surface tension would oppose hydraulic pressure at the outlet; and (3) stress corrosion cracks would be tight, rough, and tortuous, which would limit the transient response to dripping water (DIRS 177407-SNL 2007, all).

- Diversion around the waste package. The portion of the dripping water that did not flow into the waste packages would bypass the waste forms and flow directly to the invert.

- Flow into the invert. DOE has modeled all water flow from the waste packages as flowing into the invert, independent of the location of a breach on the waste package. In addition, the dripping water that diverted around the drip shields and waste packages would flow into the invert. The analysis did not include the presence of the emplacement pallets in the abstraction of engineered barrier system flow, so the water flow was modeled without resistance from the pallets.

- Imbibition flow to the invert. Water could be imbibed from the host rock matrix into the invert. The engineered barrier system thermal-hydrologic environment submodel provides the rate of water imbibition into the invert.

- Flow from the invert to the unsaturated zone. A portion of the advective flux from the invert equal to the total dripping flux would flow directly into unsaturated zone fractures. The portion of the advective flux from the invert equal to the imbibition flux to the invert would flow into the unsaturated zone matrix.

These pathways are time-dependent in the sense that waste package breaches would vary with time and local conditions in the repository. The analysis did not include the effect of evaporation on seepage water flow through the engineered barrier system, which would tend to overestimate engineered barrier system flow.

F.2.4 WASTE PACKAGE AND DRIP SHIELD DEGRADATION

A two-layer waste package would enclose the radioactive waste that DOE emplaced in the proposed repository. The layers would be of two different materials that would fail at different rates and from different mechanisms as they were exposed to repository conditions. The outer layer would be a high-nickel alloy (Alloy-22) and the inner layer would be a stainless-steel alloy. In addition, commercial spent nuclear fuel waste packages would contain a stainless-steel TAD canister. To divert dripping water from the waste package and thereby extend waste package life, DOE would place a Titanium Grade 7 drip shield over the waste packages just before repository closure. The drip shield would divert water that entered the drift from above and thereby prevent seep water from contact with the waste package. The analysis used the drip shield and waste package degradation models to simulate the degradation of these components (DIRS 180778-SNL 2007, all; DIRS 178519-SNL 2007, all). General corrosion was the only drip shield degradation mechanism DOE considered under nominal conditions because analyses showed that if other degradation mechanisms (stress corrosion cracking, localized corrosion, and microbially induced corrosion) occurred the consequences to drip shield performance would be insignificant. Three main types of waste package degradation were considered under nominal conditions—general corrosion, stress corrosion cracking, and seepage-induced localized corrosion. An additional corrosion process—microbially induced corrosion—was considered to provide enhanced general corrosion on the waste package. The analysis screened out mechanical failure of the drip shield and waste package by rock fall under nominal conditions due to low consequence. However, it included mechanical failure of the drip shield and waste package by rock fall and fault displacement in the Seismic Scenario Class. Failure mechanisms that the analysis considered included collapse of the drip shield, stress corrosion cracking of the waste package, and rupture of the drip shield and waste package.

For nominal degradation processes, output from the drip shield and waste package degradation models included time-dependent quantitative assessments of drip shield and waste package degradation and failure. Results included the time to failure by general corrosion for the drip shield and the time to initial failure by general corrosion for the waste package; time to first breach of the waste package by stress corrosion crack failure; and the degree of drip shield and waste package failure as a function of time. In the SEIS, drip shield failure by general corrosion occurred between approximately 260,000 years and 310,000 years, with the failure time different for each epistemic realization. In addition, because there was no spatial variability in drip shield corrosion rates, all drip shields in the repository failed at the same time in a given realization. The time of the first breach of the waste package would correspond to the start of waste form degradation in the breached package. The time of first breach ranged from approximately 100,000 years to 1 million years, with the breaches caused by stress corrosion cracking in the weld of the outer closure lid. General corrosion failures would start at around 400,000 years and about 10 percent of the waste packages would experience a general corrosion breach within 1 million years. Diffusion was the only transport mechanism acting to release radionuclides from a waste package when cracks were the only penetration through the waste package. The diffusive area for a single stress corrosion crack based on the geometry of an ellipsoidal crack was 7.7×10^{-6} square meter (DIRS 177407-SNL 2007, all). On average approximately 60 percent of the commercial spent nuclear fuel waste packages and 60 percent of the codisposal waste packages experienced a first breach by stress corrosion cracking by 1 million years. The average number of cracks per breached waste package at 1 million years was about 4. Advection and diffusion were the transport mechanisms acting to release radionuclides from a waste package when general corrosion breaches formed. On average only about 10 percent of the commercial spent nuclear fuel and codisposal waste packages experienced a general corrosion breach within 1 million years. The average number of general corrosion breaches (patches) at 1 million years was about 4. General corrosion breaches were represented by dividing the waste package surface into sub areas called patches. The total number of possible patches on a commercial spent nuclear fuel waste package is about 1,000 and on a codisposal waste package about 1,100.

Manufacturing and material defects could augment corrosion processes and result in early failure of the drip shield and waste package. Early failure is defined as through-wall penetration of a drip shield or waste package at a time earlier than would occur by mechanistic degradation for a defect-free drip shield or waste package. Several types of manufacturing defects (for example, base-metal flaws, improper weld filler material, improper base metal selection, improper heat treatment, improper handling, and improper stress relief) could lead to early drip shield and waste package failure. Among these defects DOE anticipates that improper heat treatment would occur most often.

An analysis of manufacturing and testing led to probability distributions for the number of drip shields and waste packages that could fail due to manufacturing and material defects. Table F-2 lists the resultant early failure unconditional probability values. The probability values in this table indicate that more than 44 percent of the TSPA-SEIS realizations would have early failed waste packages and 56 percent would have no early failed waste packages. Twenty-two percent of the realizations would have only one early failure and 9.6 percent would have two early failed waste packages. This leaves 12 percent of the remaining realizations with three or more failed waste packages. The expected number of early failed waste packages would be 1.09 (DIRS 178765-SNL 2007, all). Only 1.7 percent of the realizations would have early failed drip shields, 98 percent would have no early failed drip shields. Realizations with only one early failure would account for 1.6 percent and 0.09 percent would have two early failed drip shields. This leaves 0.02 percent of the remaining realizations with three or more failed drip shields. Because only a small number of realizations would have an early failed drip shield, the expected number of early failed drip shields would be 0.018 (DIRS 178765-SNL 2007, all).

Table F-2. Early failure unconditional probability values.

n (number of early failures)	Probability of n failures of waste packages	Probability of n failures of drip shields
0	0.558	0.9834
1	0.2237	0.0155
2	0.0955	0.0009
≥ 3	0.1228	0.0002

Source: DIRS 178765-SNL 2007, all.

It was conservatively assumed in the TSPA-SEIS that manufacturing or material defects resulted in complete failure. This representation of early drip shield and waste package failures reflects a conservative view because a manufacturing or material defect would not necessarily result in complete failure. The analysis also assumed that a waste package under an early failed drip shield would fail completely due to localized corrosion; this is conservative because a smaller failure would produce smaller releases.

ASSUMPTIONS

In the assessment of postclosure impacts, DOE sometimes used assumptions to formulate models. An assumption is a premise about some element of the modeling and usually something for which there is no absolute proof. Assumptions normally account for qualitative uncertainties (if an absolute probability cannot be assigned). Assumptions are used: (1) when there is a high certainty (although unquantified) that the premise is true, and (2) when the assumption is conservative (that is, all alternative assumptions would lead to a smaller impact). The conservative assumption is often used if there is considerable uncertainty about which alternative premise is more likely. Regulations that prescribe modeling make some assumptions necessary. A set of assumptions defines the conceptual model for the analysis. A set of alternative assumptions would represent an alternative model. Some sensitivity studies compare alternative models to help define the importance of certain assumptions, especially if there is considerable uncertainty (Chapter 5, Section 5.3.4.2.3).

Each assumption has a basis, which is the reason the assumption represents a condition of high certainty, a statement that it is mandated by a regulation, or a statement that it is conservative in relation to the outcome of impact analysis.

F.2.5 WASTE FORM DEGRADATION

The waste form degradation models evaluate the interrelationships of the in-package water chemistry, the degradation of the waste forms, and the mobilization of radionuclides (DIRS 177423-SNL 2007, all, DIRS 177418-SNL 2007, all, DIRS 180178-SNL 2007, all). The model consists of components that:

- Define the radioisotope inventories for representative commercial spent nuclear fuel and codisposal waste packages (this is the inventory abstraction that Section F.3.1 discusses in more detail).
- Evaluate in-package water chemistry. In-package chemistry is modeled in the TSPA-SEIS model using simplified expressions to define the bulk chemistry, which consists of pH, ionic strength, and total carbonate concentration as a function of time inside a waste package. The analysis used chemistry outputs to set conditions for waste form degradation and to determine dissolved concentration limits in the waste package.
- Evaluate the matrix degradation rates for commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste forms. The TSPA-SEIS model used empirical degradation rate formulas DOE developed for the three different waste forms to model degradation. DOE would combine defense spent nuclear fuel and vitrified high-level radioactive waste in codisposal waste packages.
- Evaluate the dissolved radionuclide concentration limits for aqueous phases. Dissolved radionuclide concentration limits abstraction (distributions of solubilities as a function of pH and temperature in the waste package; solubilities are checked for possible limitations due to waste form degradation rate or package inventory).
- Evaluate sorption of radionuclides in the waste package.
- Evaluate the waste form colloidal phases. The colloidal radionuclide concentration component abstraction models the formation, stability, and concentration of radionuclide-bearing colloids in the

waste package and engineered barrier system, as well as reversible and irreversible sorption of dissolved radionuclides, using empirical relationships and uncertainty distributions for sorption coefficients.

F.2.6 ENGINEERED BARRIER SYSTEM FLOW AND TRANSPORT

The waste form would be the source of radionuclides in the engineered barrier system. After a waste package failed (due to general or localized corrosion, rupture due to large seismic ground motions or fault displacements, igneous intrusion, or early waste package failure mechanisms), a portion of the water that seeped into the drift could enter the waste package if the drip shield has failed, which would mobilize radionuclides from the degraded waste form and transport them by advection into the unsaturated zone. Diffusion would be the primary transport mechanism when the water flux into the waste package was negligibly small or zero as in the case where the waste package has failed due to stress corrosion cracking. If stress corrosion cracks were the only penetrations through the drip shield and waste package, no advective transport could occur through them (DIRS 177407-SNL 2007, all). Diffusive transport would occur as a result of a gradient in radionuclide concentration and could occur at the same time as advective transport.

The abstraction simulates the following transport modes:

- Advective and diffusive transport of dissolved radionuclides in the waste package and invert to account for the dependence of diffusion on porosity, saturation, and temperature;
- Colloid-facilitated advective and diffusive transport in the waste package and invert;
- The time-dependent quantity of corrosion products inside a breached waste package;
- Radionuclide sorption onto stationary corrosion products in a breached waste package, which includes competition for a finite number of sorption sites and equilibrium and kinetic sorption-desorption processes; and
- Equilibrium linear radionuclide sorption in the invert.

The TSPA-SEIS model represents diffusion with the use of a diffusion transport equation with an empirical effective diffusivity that is a function of liquid saturation, porosity, and temperature. The analysis used sorption response surfaces based on detailed surface complexation modeling to implement the model for sorption of radionuclides on stationary corrosion products in the waste package.

A linear isotherm (constant ratio of concentration in the water to amount sorbed on the solid) would characterize sorption on invert ballast material. Advective transport is represented by a liquid transport equation with the velocity from the engineered barrier system flow abstraction.

F.2.7 UNSATURATED ZONE TRANSPORT

Unsaturated zone transport refers to the movement of radionuclides from the engineered barrier system of the proposed repository, through the unsaturated zone, and to the water table. The unsaturated zone would be the first component of the lower natural barrier to radionuclides that escaped from the repository. It would act as a barrier by delaying radionuclide movement. If the delay was long enough for significant decay of a specific radionuclide, the unsaturated zone could have a significant effect on the ultimate dose from releases of that radionuclide to the environment. The *Particle Tracking Model and Abstraction of Transport Processes* (DIRS 181006-SNL 2007, all) describes how radionuclides would move through the unsaturated zone. The unsaturated zone model considered transport through welded and nonwelded tuff and flow through the fractures and the rock matrix. In addition, the model accounted for the existence of zeolitic alterations of the tuff in some regions. The zeolitic tuffs have the characteristics of lower permeability and enhanced radionuclide sorption. The unsaturated zone water flow would provide the background on which the unsaturated zone transport took place. The model used the flow fields from the unsaturated zone flow model (Section F.2.2). Radionuclides can migrate in groundwater as dissolved molecular species or in colloids. Dissolved species would typically consist of radionuclide ions complexed with various groundwater species, but still at molecular size. Colloids are particles of solids, typically clays, silica fragments, or organics, such as humic acids or bacteria, that are larger than molecular size, but small enough to remain suspended in groundwater for indefinite periods. Colloids usually have a size range between a nanometer and a micrometer. A radionuclide could be attached to the surface or bound in the structure of the colloid.

Five basic processes affect the movement of dissolved or colloidal radionuclides:

- *Water flux and advection*. The ability of the unsaturated zone to prevent or substantially reduce the rate of movement of radionuclides depends in part on the flux of water through the unsaturated zone. This flux is distributed between faults, fractures, and the matrix of the host rock and other units in the unsaturated zone. The rate of movement or advection of radionuclides is strongly dependent on the degree of fracture flow, which, in turn, is dependent on the magnitude of the total flux. Total flux is directly dependent on the surficial recharge and infiltration that, in turn, is dependent on climatic conditions. The increase in recharge due to change in climate states could significantly reduce the capability of the unsaturated zone to reduce the rate of radionuclide advection. This reduction would be a function of (1) the increase in fracture flux and corresponding reduction in the effectiveness of matrix diffusion and (2) the rise in the water table and the associated decrease in the unsaturated zone travel distance.

- *Matrix diffusion*. Matrix diffusion results in the diffusion of dissolved radionuclides from the fractures into the matrix of the rock. Because advective transport is significantly slower in the matrix than in the fractures, matrix diffusion can be a very efficient retarding mechanism, especially for moderately to strongly sorbed radionuclides, due to the increase in rock surface accessible to sorption. Matrix diffusion is incorporated in the unsaturated zone radionuclide transport abstraction model in the TSPA-SEIS model. However, matrix diffusion of colloidally transported radionuclides has been excluded for conservatism.

- *Sorption*. Radionuclides released from the repository would have varying retardation characteristics. Several radionuclides that would be the dominant contributors to the total dose would be significantly retarded in the unsaturated zone if there was significant matrix diffusion or matrix-dominated flow in the vitric Calico Hills tuff. These would include strontium-90, cesium-137, plutonium-239 and -240, and americium-241 and -243. The sorption of the these radionuclides that diffused into the matrix or were transported in the matrix of the Calico Hills tuff would prevent their movement or significantly reduce the rate of movement from the repository to the accessible environment.

- *Colloidal transport*. Several radionuclides could move in colloidal particles in the unsaturated zone. These include plutonium-239 and -240 and americium-241 and -243. The analysis considered reversible and irreversible colloidal transport. Retardation of a large fraction of the colloidally transported radionuclides would be sufficient to prevent the movement or significantly reduce the rate of movement of these radionuclides from the repository to the accessible environment. The analysis conservatively assumed that a small fraction of the colloids would be unretarded in the unsaturated zone. The unsaturated zone transport model includes sorption of colloidal transport of radionuclides.

- *Radioactive decay and ingrowth*. As radionuclides moved along groundwater flow paths from the repository to the accessible environment, they would decay. The degree of decay would be a function of the half-life of the radionuclide in comparison to the transport time to the environment. In addition, the analysis considered the ingrowth of some radionuclides (in particular, neptunium-237 from the decay of americium-241). This included decay and ingrowth processes for dissolved and colloidal radionuclides.

The analysis implemented the unsaturated zone transport model in the TSPA-SEIS model as an embedded computer program that simulates the three-dimensional transport with a residence-time, transfer-function, particle-tracking technique. The model, which incorporates the unsaturated zone flow fields, is based on a dual-continuum formulation, which accounts for the effects of fracture flow and fracture-matrix interactions on radionuclide transport. The model includes future changes in water table elevations, which shorten the path length for unsaturated zone transport, and implements those as instantaneous changes that occur with climate change. The key parameters such as sorption coefficients, fracture frequency, fracture porosity, and colloid parameters (partitioning, retardation, colloid size distribution) were input as uncertainty distributions. The unsaturated zone radionuclide transport provides the rate and spatial distribution of radionuclide releases to the saturated zone flow and transport model as output.

F.2.8 SATURATED ZONE FLOW AND TRANSPORT

The saturated zone at Yucca Mountain is the region beneath the ground surface where rock pores and fractures are fully saturated with groundwater. The upper boundary of the saturated zone is the water table. The proposed repository would be in the unsaturated zone about 300 meters (1,000 feet) above the water table.

Underground water flows down hydraulic gradients. Based on water-level observations in area wells, groundwater near Yucca Mountain flows generally in a north-to-south direction. The major purpose of the Saturated Zone Flow and Transport Model Abstraction (DIRS 177390-SNL 2007, all) is to evaluate the migration of radionuclides from their introduction at the water table below the proposed repository to the point of release to the biosphere. A radionuclide could move through the saturated zone as a dissolved solute or a colloid. The input to the saturated zone is the spatial and temporal distribution of mass flux of radionuclides from the unsaturated zone. The output of the saturated zone flow and transport model is a mass flow rate of radionuclides in the water that a hypothetical farming community would use.

F.2.8.1 Saturated Zone Flow

The saturated zone flow model (DIRS 177391-SNL 2007, all) receives inputs from the unsaturated zone flow model and produces outputs, in the form of flow fields, for the saturated zone transport model. The saturated zone flow model incorporates a significant amount of geologic and hydrologic data from drill holes near Yucca Mountain. The saturated groundwater flow in the vicinity of Yucca Mountain can be estimated by knowing the porosity of the flow media, the hydraulic conductivity, and the recharge of water into the flow media. Water flow in the saturated zone occurs through two rock types—fractured volcanic rocks and alluvium. The groundwater flow rates, the rate of transport of radionuclides, and the radionuclide retardation characteristics of these different rock types are significantly different. In addition to the differences in flow and transport characteristics of the different lithologic units in the saturated zone, the presence of discrete flow features in the fractured tuff units would affect the rate of movement of radionuclides to the accessible environment. Matrix flow in the alluvium would provide a significant reduction in the movement of radionuclides to the environment. The primary tool used to describe saturated zone flow is a numerical model in three dimensions. DOE developed the three-dimensional saturated zone flow model specifically to determine the groundwater flow field at Yucca Mountain. The model produced a library of flow fields (maps of groundwater fluxes) that the saturated zone transport model used.

F.2.8.2 Saturated Zone Transport

The saturated zone transport model (DIRS 177390-SNL 2007, all) receives inputs in the form of radionuclide mass fluxes from the unsaturated zone transport model and produces outputs in the form of radionuclide mass fluxes to the biosphere model. It incorporates laboratory and field data from a variety of sources.

Radionuclides released from a repository at Yucca Mountain to the groundwater would enter the saturated zone beneath the repository and travel southeast and then south toward the Amargosa Desert. The groundwater could transport radionuclides in two forms: as dissolved species or bound in colloids. Advection would be the principal transport mechanism for dissolved and colloidal radionuclides in the saturated zone. The advective flux would depend on the hydrogeologic characteristics of the water-conducting features in the saturated zone and on the groundwater flux through these features. Dispersive processes would tend to spread transient radionuclide pulses that could move to the saturated zone (for example, following a water table rise due to climate changes).

The analysis primarily used a three-dimensional, particle-tracking model for transport through the saturated zone (DIRS 177390-SNL 2007, all). This model generated a library of breakthrough curves—distributions of transport times—along with a time-varying source term from the unsaturated zone, to calculate the releases at the boundary between the geosphere and biosphere. The model accounted for the flow of groundwater and its interaction with media along the flow path. In the volcanic rocks that comprise the saturated media in the immediate vicinity of Yucca Mountain, groundwater flows primarily through fractures, while a large volume of water is relatively immobile in the surrounding rock matrix. Radionuclides would travel with the moving fracture water but, if dissolved, could diffuse between the matrix water and fracture water. This transfer between fracture and matrix water is characteristic of a dual-porosity system. The saturated zone transport model is a dual-porosity model. The media at greater distances from Yucca Mountain are alluvial gravels, sands, and silts. The model simulated these areas as more uniformly porous.

Because the three-dimensional particle tracking model does not consider ingrowth from decay chains, it is used to evaluate only the first and second members of decay chains. The influence of a decaying parent species on the second member of a decay chain is approximated with the use of an inventory-boosting method in which the parent species release from the unsaturated zone is predecayed and added to the decay species source term from the unsaturated zone model. A one-dimensional saturated zone model accounts for decay and ingrowth of all other members of a decay chain during transport. This model was incorporated directly in the GoldSim model as a series of pipes. The advantage of using the one-dimensional model is that the radionuclide masses can be accounted for directly. The disadvantage is that the flow and transport geometry is necessarily simplified.

F.2.9 BIOSPHERE

If the radionuclides were removed from the saturated zone in water pumped from wells, the radioactive material could result in dose to humans in several ways. For example, water could be used to irrigate crops that would be consumed by humans or livestock, to water stock animals that would be consumed by humans as dairy or meat products, or to provide drinking water for humans. In addition, if the water from irrigation wells evaporated on the surface, the radionuclides could be left as fine particulate matter that could be picked up by the wind and inhaled by humans. The biosphere model (DIRS 177399-SNL 2007, all) tracks the environmental transport of radionuclides through the biosphere and calculates annual radiation exposure to a person who lived in the general vicinity of the proposed repository if there was a release of radioactive material to the biosphere after closure. The primary outputs of the biosphere model are sets of biosphere dose conversion factors equivalent to the annual dose from all potential exposure pathways that the person would receive as a result of a unit concentration of a radionuclide in groundwater (DIRS 177399-SNL 2007, all) or volcanic ash (DIRS 177399-SNL 2007, all). The biosphere scenarios assumed a reference person who lived in the Amargosa Valley region at various distances from the repository. People who lived in the town of Amargosa Valley would be the group most likely to be affected by radioactive releases, specifically an adult who lived year-round at this location, used a well as the primary water source, and otherwise had habits similar to those of the inhabitants of the region (such as the consumption of local foods). Because changes in human activities over millennia are unpredictable, the analysis assumed that the present-day reference person was the basis for future inhabitants. The EPA standard (40 CFR Part 197) provides the definition for the reference person (the RMEI).

DOE did not use the biosphere model to evaluate the chemically toxic materials because there are no usable comparison values for radiological and nonradiological doses. Rather, the Department made a separate analysis of concentrations of these materials that compared the concentrations to available regulatory standards, such as the Maximum Contaminant Level Goal if available or to the appropriate Oral Reference Dose.

The biosphere is the last component in the chain of TSPA-SEIS model subsystem components. There are two connections between the biosphere model and other TSPA models. One is for the scenario classes and modeling cases that involve exposure through the groundwater pathway (Nominal, Drip Shield and Waste Package Early Failure, Seismic Ground Motion Damage and Fault Displacement, and Igneous Intrusion), where the biosphere is coupled to the saturated zone flow and transport model; and the other is for the Volcanic Eruption Modeling Case, where the biosphere is coupled to the volcanic eruption model. For the Human Intrusion Scenario, the biosphere model is coupled with the saturated zone flow and transport model.

F.2.10 IGNEOUS ACTIVITY DISRUPTIVE EVENTS

Igneous activity could compromise the natural and engineered barriers in the proposed repository. The TSPA-SEIS model represents igneous activity with the Igneous Scenario Class, which includes features, events, and processes that describe the possibility that low-probability igneous activity could affect repository performance. Two modeling cases in the TSPA simulate the significant features, events, and processes: The first is the Igneous Intrusion Modeling Case, which addresses the possibility that magma (molten rock), in the form of a dike (ridge of material), could intrude into the repository and disrupt expected repository performance; the second is the Volcanic Eruption Modeling Case, which includes features, events, and processes that describe an eruption that would rise through the repository footprint and damage a number of waste packages. The low-probability volcanic eruption could disperse volcanic tephra (solid material of all sizes explosively ejected from a volcano into the atmosphere) and entrained waste into the atmosphere and deposit it on the surface where soil and near-surface geomorphic (of or relating to the form or surface features of the earth) processes would redistribute it.

The intrusion of a dike or eruption of volcanic material through the repository would not substantially affect the capability of the natural barriers at Yucca Mountain to prevent or reduce the flow of water or the movement of radionuclides in groundwater away from the repository. Movement of radionuclides entrained in magma (rather than contained in groundwater) through the natural system during a volcanic eruption would have some adverse effect on the ability of the natural barrier system to prevent a release of radionuclides. Igneous or volcanic events could adversely affect the engineered barrier system's ability to prevent or reduce the release of radionuclides to the natural system.

If igneous activity occurred at Yucca Mountain, possible effects on the repository could fall into three areas:

- Igneous activity that would not directly intersect the repository (no effect on dose from the repository)
- Volcanic eruptions in the repository that would result in the entrainment of waste material in the volcanic magma or pyroclastic material and would bring waste to the surface (which would result in atmospheric transport of volcanic ash contaminated with radionuclides and subsequent human exposure downwind)
- An igneous intrusion that intersected the repository (no eruption but damage to waste packages from exposure to the igneous material that would enhance release to the groundwater and, thus, transport to the biosphere)

Field geologic investigations, laboratory analyses, analogue studies, and reviews of published literature provide the technical basis for the description of past igneous activity in the Yucca Mountain region and for the development of the conceptual, process, and consequence models that represent potential future events. The process models have been used to develop simplified models or abstractions that are incorporated in the TSPA-SEIS model to generate a probabilistic representation of the likelihood and consequences of the Igneous Scenario Class.

DOE addressed the probability of a future igneous event that intersected the repository through a probabilistic volcanic hazard analysis that used expert judgment to consider applicable geologic processes and uncertainty. Probability distributions were developed to define the likelihood of a volcanic event and the length and orientation of dikes that could intersect the repository footprint. Information from the probabilistic volcanic hazard analysis was used to estimate the number of eruptive centers in the footprint. The mean annual frequency of intersection of the repository footprint by a potential future igneous event would be 1.7×10^{-8}, which is equivalent to an annual probability of about 1 in 60 million. The 5th- and 95th-percentile uncertainties associated with the frequency of intersection span almost 2 orders of magnitude, from 7.4×10^{-10} magnitude to 5.5×10^{-8} (DIRS 169989-BSC 2004, Table 7-1), or about 1 in 1.4 billion to 1 in 18 million per year. The results of the probabilistic volcanic hazard analyses indicate that the mean annual probability of future igneous activity at Yucca Mountain would be greater than 1×10^{-8}; therefore, the igneous scenario class for disruptive events would be an unlikely event that could affect repository performance.

F.2.10.1 Igneous Intrusion Modeling Case

In the Igneous Intrusion Modeling Case, a basaltic dike would intersect one or more emplacement drifts and magma would flow in and fill them, which would engulf the waste packages and drip shields. The magma would then cool and solidify. The model conservatively assumes that such an intrusion would destroy all waste packages in the repository; that is, all waste packages would lose structural integrity and their ability to prevent or limit the flow of water, and the movement of radionuclides would be completely compromised. After the drifts returned to temperatures lower than the boiling point of water, seepage into drifts would resume. The model conservatively assumes that the cooled magma would have hydrologic properties similar to the surrounding welded tuff, so the percolation flux into the intruded drift and waste package would be equivalent to percolation flux through the host rock. The rate of transport of radionuclides would depend on the temperature and chemistry of the groundwater. Thus, the percolation of water through cooled basalt would provide a mechanism for radionuclide release and transport.

The Igneous Intrusion Modeling Case simulates flow and transport through the engineered barrier system and the unsaturated and saturated zones in the same manner as the Nominal Scenario Class Modeling Case.

F.2.10.2 Volcanic Eruption Modeling Case

The Volcanic Eruption Modeling Case considers the intrusion of one or more dikes into the repository and the formation of one or more eruptive conduits that would intersect emplacement drifts. Magma would destroy the waste packages in the conduits and entrain their waste. Contaminated volcanic tephra would be erupted into the atmosphere in a vertical column that reached altitudes up to 13 kilometers (8 miles), and would be dispersed by wind to the accessible environment. Surface processes (erosion and deposition by water and wind) could redistribute the tephra. DOE used information from the probabilistic volcanic hazard analysis to estimate the probability that one or more eruptive centers would form in the repository to assess the number of waste packages in the eruptive conduits. The Volcanic Eruption Modeling Case provides the TSPA-SEIS model with the number of waste packages that volcanic conduits would intercept, the aerial density of contaminated tephra, and the concentration of contaminated tephra from redistribution.

F.2.11 SEISMIC ACTIVITY DISRUPTIVE EVENTS

The Seismic Scenario Class describes future performance of the repository system if seismic activity disrupted the system. It represents the direct effects of vibratory ground motion and fault displacement associated with seismic activity, and it considers indirect effects of drift collapse. The Seismic Scenario Class considers the effects of seismic hazards on drip shields and waste packages. It also considers changes in seepage, waste package degradation, and flow in the engineered barrier system that could result from a seismic event. The Seismic Consequence Abstraction documents the conceptual models and abstractions for the mechanical response of engineered barrier system components to seismic hazards at a geologic repository (DIRS 176828-SNL 2007, all).

The Seismic Scenario Class estimates the mean annual dose due to a seismic event by accounting for the probability of occurrence of the event in terms of its mean annual exceedance frequency. The estimate of mean annual dose considers the relevant processes that would come into play and affect system performance. The Seismic Scenario Class has two modeling cases: The Seismic Ground Motion Modeling Case includes waste packages that would fail solely due to the ground motion damage associated with the seismic event; the Seismic Fault Displacement Modeling Case includes only those waste packages that would fail due to fault displacement damage. These two cases have the same framework as the Nominal Scenario Class Modeling Case; that is, the framework includes the TSPA-SEIS model components to evaluate the mobilization of radionuclides exposed to seeping water, released from the engineered barrier system, transported in the unsaturated zone down to the saturated zone, and transported in the saturated zone from the repository to the location of the RMEI. Each component considers the effects of the seismic event, as appropriate.

F.2.11.1 Seismic Activity

The probabilistic seismic hazard analyses for ground motion used an expert elicitation process to determine the annual probability at which various levels of ground motion would be exceeded at Yucca Mountain (DIRS 103731-CRWMS M&O 1998, all). The results of this process provided hazard curves for a reference rock outcrop with the same seismic-wave propagation properties as the rock at the repository horizon inside Yucca Mountain. These results were modified to account for the effects of the site-specific geology of Yucca Mountain. The effects of the site materials [approximately the upper 300 meters (980 feet) of rock and soil] on ground motions at the waste emplacement level were calculated with the use of a ground motion site-response model. The acceleration response spectrum consists of the maximum response of a single-degree-of-freedom oscillator system (for a given damping ratio) to an input motion (accelerogram) as a function of the natural frequency of the system. The outputs of the site-response model (location-specific response spectra and peak ground velocity values) were used to scale recordings from past earthquakes to produce acceleration and velocity time histories (seismograms) for dynamic analyses to support postclosure performance assessment. Finally, when the models in the probabilistic seismic hazard analyses were applied, low-probability ground motion values were allowed to increase without bounds to eventually reach levels that are not credible for Yucca Mountain; that is, at low annual probabilities of exceedance, the calculated ground motions would produce strain levels in excess of the strength of the rock mass. Therefore, a separate analysis was performed to bound peak horizontal ground velocity at the waste emplacement level, with consideration of the maximum strain levels repository rocks could sustain (DIRS 170137-BSC 2005, Section 6). As shown in Figure F-2, the damage as a function of peak ground velocity level would be bounded by the combined hazard curve that results in a maximum peak ground velocity of approximately 4 meters (13 feet) per second at the 1×10^{-8} annual exceedance frequency. The analyses for the Seismic Scenario Class, therefore, fulfill the 10 CFR 63.114(d) requirements for performance assessment to consider events that have a frequency of at least 1×10^{-8} per year (1 chance in 10,000 of occurring within 10,000 years). The emphasis on peak

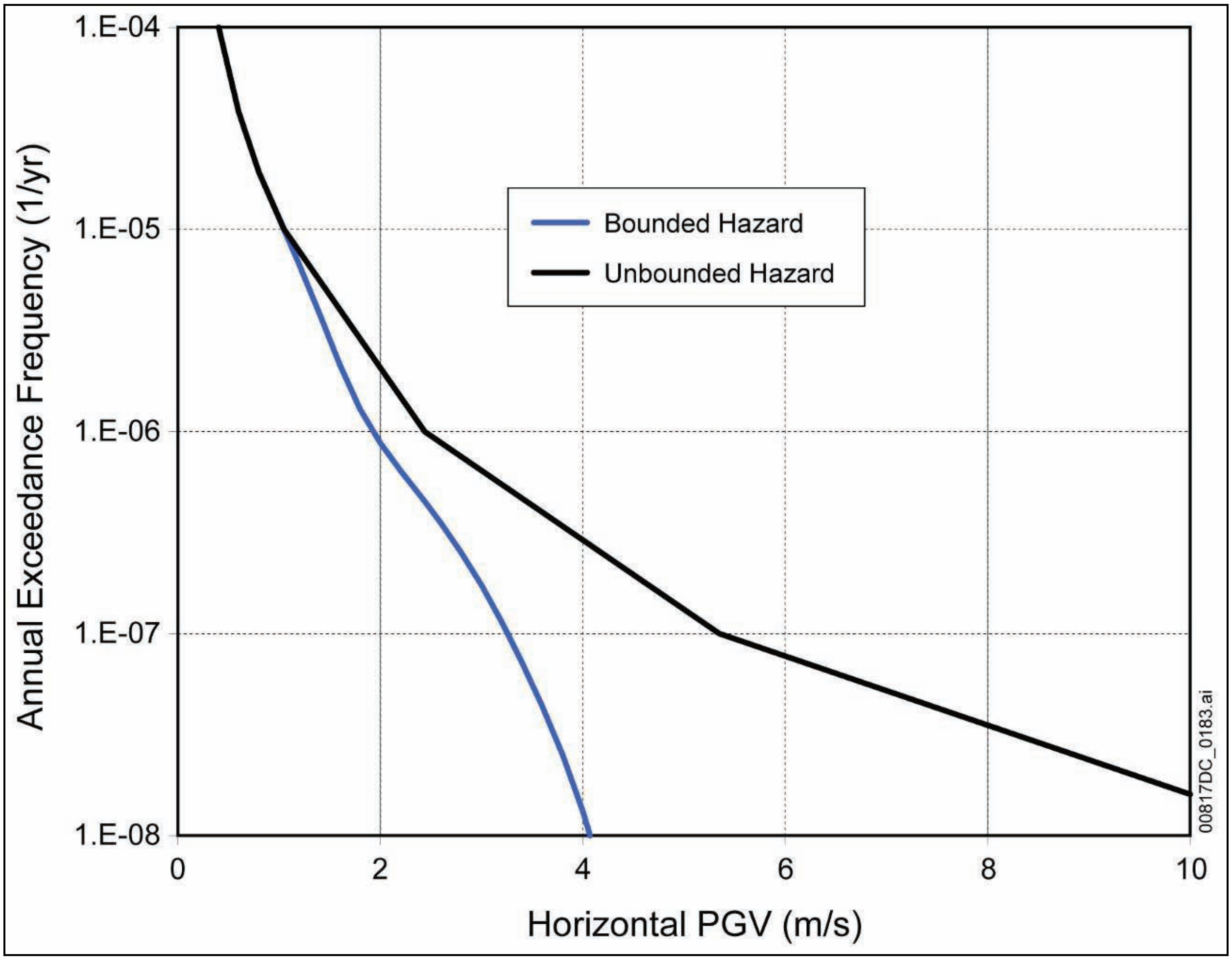

Figure F-2. Hazard curve for the seismic scenario class.

horizontal ground velocity reflects the use of that ground motion measure to set parameters for rock fall and damage to engineered barrier system features for postclosure analyses.

The fault displacement analysis derives from the probabilistic seismic hazard analyses. This analysis used an expert elicitation process to determine how the annual probability of exceedances for fault displacement at the surface would vary as a function of the size of the displacement.

F.2.11.2 Mechanical Damage to the Engineered Barrier System

The Seismic Consequence Abstraction documents models for mechanical damage to the engineered barrier system from seismic activity (DIRS 176828-SNL 2007, all). The Seismic Scenario Class modeling cases consider vibratory ground motion, rock fall, and drift collapse from ground motion and fault displacement.

The seismic damage models for this Repository SEIS represent the current waste package design and respond to the requirement to analyze repository releases over periods that extend well beyond 10,000 years. The presence of a standardized transportation, aging, and disposal (TAD) canister system (DIRS 177627-BSC 2006, all) is represented in the structural response calculations and corresponding damage abstractions. The degradation and potential failures of waste package components, the drip shield plates, and the drip shield framework due to general corrosion is represented in the structural response calculations and resultant damage abstractions. General corrosion thins and weakens the drip shields and waste packages over long time periods by gradually thinning the drip shield plates and framework and waste package outer barrier. Thinning makes these components more susceptible to being damaged by vibratory ground motion. In addition, once a waste package is breached by a through-wall crack or general corrosion the waste package internal structures could degrade and reduce the structural resilience of the waste package. These factors were included in the TSPA-SEIS seismic damage calculations. Last, the TSPA-SEIS model considered the cumulative effects from multiple seismic events over very long time scales. The seismic damage abstractions capture the full range of these changes, with the associated uncertainties, for the Seismic Scenario Class for TSPA-SEIS.

F.2.11.3 Ground Motion Damage Modeling Case

Seismic events capable of causing damage in the Seismic Ground Motion Modeling Case could occur with a horizontal peak ground velocity greater than 0.219 meters per second and mean exceedance frequencies smaller than 4.28×10^{-4} per year. Seismic events were modeled as Poisson processes that were generated randomly with the specified rate of 4.28×10^{-4} per year (equal to the difference between the minimum annual exceedance frequency of 1×10^{-8} per year and the maximum annual exceedance frequency of 4.287×10^{-4} per year). The duration of the dose assessment ends is specified by EPA to end at 1 million years. During this period, the number of seismic events with the potential to damage engineered barrier system components would be, on average 428 events (computed by multiplying the specified rate of the Poisson process, 4.28×10^{-4} per year, by the simulation time period of 1 million years), so multiple seismic events would occur in each realization of the TSPA-SEIS model. The model accounts for the potential for deformation and rupture of engineered barrier system components from multiple seismic events. The probability of damage from an event was calculated separately for the codisposal and commercial spent nuclear fuel waste packages due to the inclusion of the transport, aging, and disposal canister in the commercial spent nuclear fuel waste packages, which increased their structural strength. The structural damage from vibratory ground motion would be a function of the amplitude of the ground motion, expressed as horizontal peak ground velocity at the repository horizon. The peak ground velocity for a particular mean annual exceedance frequency, λ_S, is defined by the mean bounded hazard curve in Figure F-2. Note that since the value of the largest exceedance frequency in this figure is 1.0×10^{-4} per year, extrapolation was used to determine the peak ground velocities corresponding to exceedance frequencies between 1.0×10^{-4} per year and 4.28×10^{-4} per year. The extent of drift collapse, rock fall, and damage to the waste packages and drip shields was determined from rock fall and structural response calculations for different peak ground velocity values in *Seismic Consequence Abstraction* (DIRS 176828-SNL 2007, all). The same degree of damage to the drip shields and the same degree of damage to the waste packages were applied to all drip shields and waste packages; that is, there would be no spatial variability in degrees of damage from vibratory ground motion. The mechanical response of a drip shield and waste package would be determined by the time-dependent thickness of the drip shield and waste package components, dynamic and static rock fall loads on the drip shield and waste package, residual stress thresholds for the drip shield and waste package, and horizontal component of peak ground velocity. The mechanical response to vibratory ground motion could produce the following significant changes in the engineered barrier system components and the in-drift environment:

- Drift collapse and changes in seepage flux, temperature, and relative humidity for the emplacement drifts.

- Damage to the waste package (expressed as an area of stress corrosion cracks on the waste package surface) or by rupture/puncture probability of the waste package outer barrier, as a result of deformation due to vibratory motion while the drip shield is intact and protects the waste package from rock fall.

- Damage to the drip shield plates (expressed as an area of stress corrosion cracks on the drip shield surface) or rupture/puncture probability as a result of accumulated rock fall or impact from rock blocks.

- Probability of failure (fragility) of the drip shield plates by tensile tearing or buckling of the drip shield framework as a result of accumulated rock fall and dynamic load amplification for future states of general corrosion thinning.

- Damage to the waste package (expressed as an area of stress corrosion cracks on the waste package surface), or rupture/puncture probability of the waste package outer barrier, as a result of drip shield framework buckling collapse. The drip shield continues to act as a seepage barrier, but mechanically loads the waste package outer barrier with static and dynamically-amplified rubble loads. This accounts for future states of general corrosion thinning of the drip shield framework, waste package outer barrier, and degradation of waste package internals.

- Damage to the waste package (expressed as an area of stress corrosion cracks on the waste package surface), or rupture/puncture probability of the waste package outer barrier, as a result of drip shield plate tearing failure. The drip shield fails as a seepage and rock fall barrier, with subsequent rubble in direct contact with the waste package outer barrier, thus applying static and dynamically-amplified rubble loads. This accounts for future states of general corrosion thinning of the drip shield plates, waste package outer barrier, and degradation of waste package internals.

- Failure of the fuel cladding. Failure of the fuel cladding could occur from fuel assembly accelerations during the seismic event. However, the TSPA-SEIS does not take credit for the cladding as a barrier to radionuclide release, so it does not incorporate the dynamic response of the cladding and associated damage abstraction.

- The most likely failure mechanism from a seismic event was accelerated stress corrosion cracking in the damaged areas that exceeds the residual stress threshold for Alloy 22 (the waste package outer barrier). Other failure mechanisms as noted above included the potential for rupture or puncture of the outer corrosion barrier of the waste package in response to a high amplitude low probability earthquake after general corrosion has significantly weakened the engineered barrier system components. Stress corrosion cracks on the waste package surface would be a potential pathway for diffusive transport of radionuclides out of the waste package. Rupture or puncture of the waste package would be a potential pathway for advective transport of radionuclides out of the waste package.

F.2.11.4 Fault Displacement Modeling Case

Seismic events capable of causing damage in the Seismic Fault Displacement Modeling Case would not occur with mean exceedance frequencies greater than 2×10^{-7} per year. For a fault displacement along an emplacement drift, a sudden discontinuity in the floor and roof of the drift could occur and, if severe enough, could cause shearing failure of a waste package and drip shield. If a waste package was breached by fault displacement, the damaged area on the waste package would be determined by sampling a uniform distribution with a lower bound of zero and an upper bound equal to the area of the waste package lid. The drip shield for this waste package is also assumed to breach (DIRS 182846-SNL 2007, all).

The area on the waste package represents the extremes of response. The damaged area could be none for a package that experienced very minor crimping without breach. It could be as large as the waste package lid if the lid welds were broken from severe crimping of the package due to fault displacement. The expected number of waste package failures that could occur would depend on the annual exceedance frequency of a seismic event and could range from 25 waste packages for an annual exceedance frequency of approximately of 2×10^{-7} per year to 214 waste packages for a very low probability, annual exceedance frequency of 2.6×10^{-8} per year. These numbers of waste packages would be a small fraction of the total number of waste packages in the repository. The estimated number of failed waste packages is based on an understanding of the displacements that could occur on these faults and geometric considerations, as described in *Seismic Consequence Abstraction* (DIRS 176828-SNL 2007, all). The conceptual model specifies that when a waste package failed from fault displacement, the associated drip shield and fuel rod cladding would also fail. A sheared drip shield would allow all seepage to pass through it; that is, the damaged area would be the total surface area of the drip shield, so there would be no flux splitting (diversion of seepage) (DIRS 176828-SNL 2007, all).

F.2.12 NUCLEAR CRITICALITY

A nuclear criticality occurs when sufficient quantities of fissionable materials come together in a precise manner and the required conditions exist to start and sustain a nuclear chain reaction. In the proposed repository, one of the required conditions would be the presence of a moderator, such as water, in the waste package. The waste package design would make the probability of a criticality inside a waste package extremely small. In addition, based on an analysis of anticipated repository conditions, the accumulation of a sufficient quantity of fissionable materials outside the waste packages in the precise configuration and with the required conditions to create a criticality would be very unlikely. As a result, nuclear criticality has been excluded from the SEIS.

F.3 Inventory

This section discusses the inventories of waterborne radioactive materials DOE used to estimate radiological impacts, and some nonradioactive, chemically toxic waterborne materials in the repository environment that could present health hazards. It also discusses the inventory of atmospheric radioactive materials.

F.3.1 INVENTORY FOR WATERBORNE RADIOACTIVE MATERIALS

There would be more than 200 radionuclides in the materials in the repository. In the Proposed Action, these radionuclides would be present in five basic waste forms—commercial spent nuclear fuel, mixed oxide fuel and plutonium ceramic (plutonium disposition waste), borosilicate glass formed from liquid wastes on DOE sites (high-level radioactive waste), DOE spent nuclear fuel, and naval spent nuclear fuel (DIRS 180472-SNL 2007, all). DOE would place these wastes in several different types of waste packages of essentially the same construction but of varying sizes and with varying types of internal details. It is neither necessary nor practical to model the exact configuration of waste packages for postclosure performance assessment. The details of each package design are not significant parameters in the modeling of processes for waste package degradation, waste form degradation, and radionuclide transport. Construction of a TSPA-SEIS model with each waste package and its unique design would result in a model too large to run on any available computer in a practical time.

DOE developed the abstracted inventory to maintain essential characteristics of the waste forms for input to the TSPA-SEIS model. The TSPA-SEIS model is a high-level system model that performs hundreds of calculations in a Monte Carlo framework. To make such a calculation practicable, DOE had to reduce highly complex descriptions or behaviors to simplified concepts that capture the essential characteristics. In the case of inventory, DOE considered the highly complex array of waste streams for the five fundamental waste categories in the development of the abstraction to representative waste packages that captures the essential features of the total inventory of radionuclide materials. The analysis used two representative types—a commercial spent nuclear fuel waste package and a codisposal waste package that would contain DOE spent fuel and vitrified high-level radioactive waste. For this analysis, naval spent fuel was conservatively modeled as commercial spent fuel (DIRS 182846-SNL 2007, all). The plutonium disposition waste was split into the commercial spent nuclear fuel package (mixed-oxide fuel) and codisposal package (immobilized plutonium in a high-level waste container) (DIRS 177424-SNL 2007, all). Table F-3 summarizes the abstracted inventory. Note that, as discussed in Chapter 5, Section 5.2.1, the TSPA simulations presented in this Repository SEIS for the first 10,000 years after closure were not based on the 32 radionuclides listed in Table F-3, but on 29 radionuclides. The three radionuclides—chlorine-36, selenium-79, and tin-126—were excluded from the assessment of postclosure repository performance for the first 10,000 years after repository closure. The exclusion of these three radionuclides from the analysis had an insignificant impact on projected doses as shown. Note also that the abstracted inventory does not apply to any other analysis, because it does not specifically model each waste form but rather models a surrogate waste form that is a useful and defensible abstraction for the purpose. The averaging, blending, and screening of radionuclides to reduce the total number, while retaining essential physical characteristics of the waste, were tailored to the TSPA-SEIS model. Therefore, a comparison of this abstracted inventory with other abstractions for other analyses would not be valid.

F.3.2 INVENTORY FOR WATERBORNE CHEMICALLY TOXIC MATERIALS

DOE would use several corrosion-resistant metals that contain chemically toxic materials in the construction of the repository. The Department used a screening analysis in the Yucca Mountain FEIS to determine which, if any, of these materials would have the potential for transport to the accessible environment in sufficient quantities to be toxic to humans. Chemicals in the EPA substance list for the Integrated Risk Information System (DIRS 103705-EPA 1997, all; DIRS 148219-EPA 1999, all; DIRS 148221-EPA 1999, all; DIRS 148224-EPA 1998, all; DIRS 148227-EPA 1999, all; DIRS 148228-EPA 1999, all; DIRS 148229-EPA 1999, all; DIRS 148233-EPA 1999, all) were evaluated to determine a

Table F-3. Initial radionuclide inventories (grams per package) in 2117 for each idealized waste package type in the TSPA-SEIS model.[a]

Radionuclide	Commercial spent nuclear fuel package	Codisposal package
Actinium-227	0.00000627	0.00233282
Americium-241	9,838.2	249.081
Americium-243	1,234.2	7.2453
Carbon-14	1.3418	1.791
Cesium-135	4,359.9	224.397
Cesium-137	1,861.1	53.842
Chlorine-36	3.2296	4.2292
Curium-245	17.428	0.145759
Iodine-129	1,730	108.3
Lead-210	0	0.0000000233
Neptunium-237	5318.8	216.66
Protactinium-231	0.012205	3.6655
Plutonium-238	1,022.2	25.9096
Plutonium-239	43,143	2,761.11
Plutonium-240	20,391	476.687
Plutonium-241	240.33	0.468165
Plutonium-242	5,279.5	34.0844
Radium-226	0.00012909	0.000207
Radium-228	0.000000000019	0.0000208233
Selenium-79	41.895	13.8272
Strontium-90	745.69	27.8785
Technetium-99	7,548.8	1,167.96
Thorium-229	0.0000207	0.532074
Thorium-230	0.43187	0.2419906
Thorium-232	0.056268	51,500
Tin-126	462.94	26.3937
Uranium-232	0.0061966	0.53893173
Uranium-233	0.13657	557.195
Uranium-234	2,239.2	521.445
Uranium-235	62,661	26,516.4
Uranium-236	38,507	1,314.216
Uranium-238	7,820,000	921,000

Source: DIRS 182846-SNL 2007, all.

a. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages DOE emplaced in the proposed repository could be different.

concentration that could occur in drinking water downgradient from the repository. The chemicals on that list that would be in the repository are barium, boron, cadmium, chromium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, uranium, vanadium, and zinc. These chemicals would occur in construction materials of the repository and waste package and in the waste forms in the waste packages.

Only a few waste packages would fail during the first 10,000 years (Section F.2.4). The period of consideration for chemically toxic material impacts is 10,000 years. Therefore, only toxic materials outside the waste package were of concern in this analysis. The Yucca Mountain FEIS described a screening analysis of materials in the proposed repository (DIRS 155970-DOE 2002, p. I-29), which this

Repository SEIS incorporated by reference. The materials of concern from that screening analysis are chromium, copper, manganese, molybdenum, nickel, and vanadium.

F.4 Postclosure Radiological Impacts

For the Proposed Action, DOE conducted a detailed postclosure consequence analysis to assess compliance with the individual protection and groundwater protection standards (40 CFR 197.20 and 40 CFR 197.30). The analysis provided projections of doses and radionuclide concentrations for periods up to 10,000 years after closure and the post-10,000-year period. The dose calculated for comparison to individual protection standards is the mean annual dose for the first 10,000 years after closure and median annual dose for the post-10,000-year period.

The individual protection and groundwater standards apply to the designated location of the RMEI, which is prescribed in the EPA regulation as the farthest southern point at the boundary of the controlled area and the accessible environment (40 CFR 197.12). This location is about 18 kilometers (11 miles) downgradient from the repository. It corresponds to where the RMEI would consume and use groundwater. DOE evaluated compliance at the point where the highest radionuclide concentration in the simulated contamination plume would cross the southernmost boundary of the controlled area (at a latitude of 36 degrees 40 minutes 13.6661 seconds north) (40 CFR 197.21 and 197.31).

For the individual protection standard, DOE estimated the mean and median annual individual doses by combining performance assessment results for four primary scenario classes:

- Nominal Scenario Class (natural evolution of the repository system in the absence of disruptive events),
- Early Failure Scenario Class (early failure of waste packages and drip shields due to material defects, process failures, human errors),
- Igneous Scenario Class (hypothetical intrusion and volcanic eruption), and
- Seismic Scenario Class (vibratory ground motion and fault displacement).

For the individual and groundwater protection standards, DOE computed the estimates of annual doses and radionuclide concentrations for the RMEI location using the NRC-specified representative volume of 3.7 million cubic meters (3,000 acre-feet) of groundwater (10 CFR 63.332) that would be drawn annually from the aquifer at the accessible environment to calculate the concentration of radionuclides. The TSPA-SEIS model collects all the radionuclides that would be released from the repository and transported through the unsaturated and saturated zones to the accessible environment and subsequently mixed in the representative volume or annual water demand of the RMEI.

The postclosure consequence analysis for the Proposed Action conformed to the NRC technical requirements (10 CFR 63.114). The TSPA-SEIS model calculates estimates of projected annual dose and groundwater concentrations in a probabilistic framework. It uses a Monte Carlo simulation technique to address the epistemic uncertainty and aleatory uncertainty in the values of the input parameters. It generates multiple realizations of input parameters by sampling from assigned probability distributions and simulating the performance of the repository system. As noted above, the postclosure analysis

COLOR FIGURES

The figures illustrating results of the performance analysis presented in Chapter 5 and Appendix F can be found in color at the Office of Civilian Radioactive Waste Management website: http://www.ocwrm.doe.gov/

provided projections of doses and radionuclide concentrations for the first 10,000 years after closure and for the post-10,000-year period. For all scenario classes, the analysis for this Repository SEIS made separate TSPA calculations for each period to ensure adequate numerical accuracy and statistical stability of results. For example, to achieve sufficient accuracy in the 10,000-year period results, it was necessary to implement much smaller time steps in the numerical calculations. The largest time step in the 10,000-year calculations was 40 years. The largest time step in the post-10,000-year calculations was 4,000 years. In addition, the smallest time step in the post-10,000-year calculations was 400 years, which was used as the time step for the first 10,000 years. As a result, the projected doses at 10,000 years, for the 10,000 years and post-10,000-year calculations, would in general be different but sufficiently accurate to project groundwater concentrations and mean and median annual doses.

A plot of multiple dose history curves is called a horsetail plot. The plot of Nominal Scenario Class Modeling Case results in Figure F-3 is an example of a horsetail plot. Each dose-versus-time curve in Figure F-3 represents the estimates of calculated time-dependent dose for a single realization or sample of epistemic uncertainty. The TSPA-SEIS model generated the entire set of dose-versus-time curves by repeating this process a number of times in a single looping process.

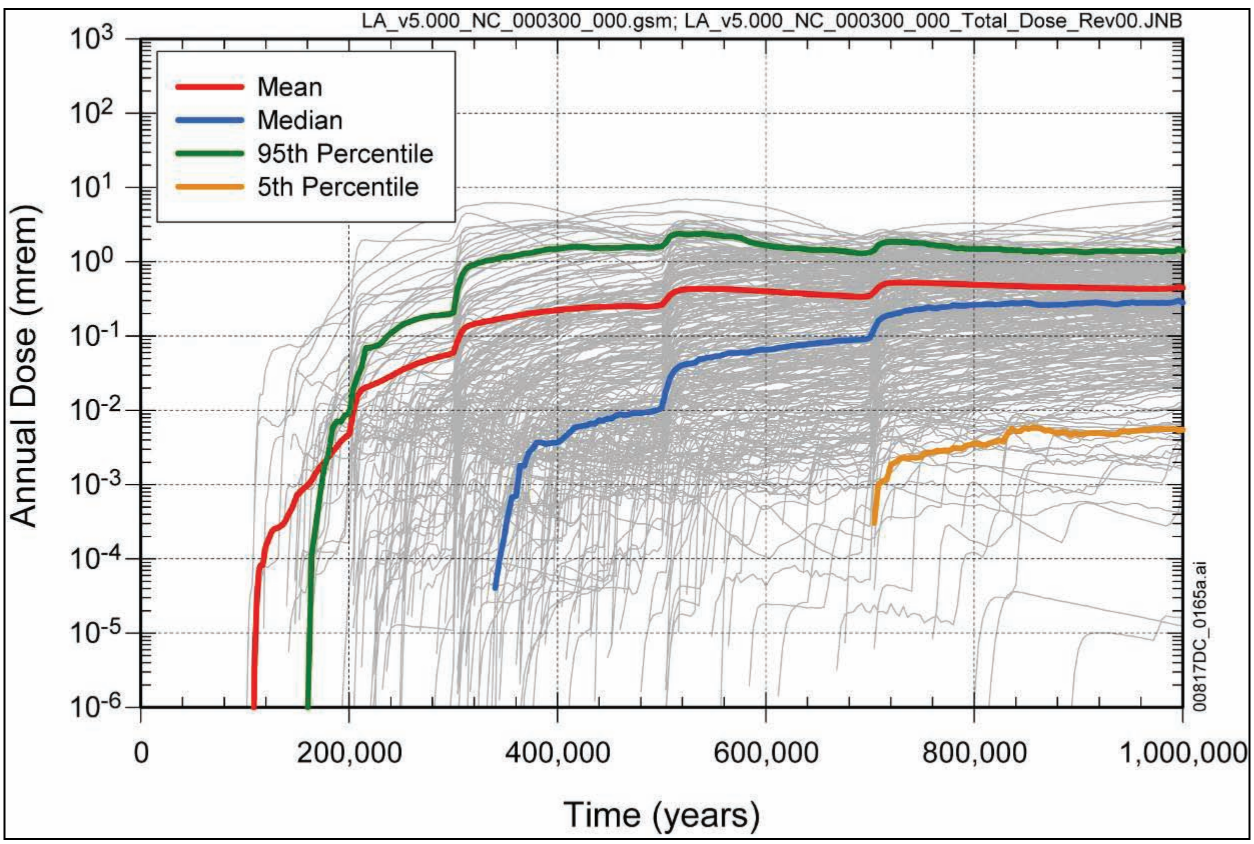

Figure F-3. Projected annual dose for the Nominal Scenario Class Modeling Case for the post-10,000-year period.

For the Repository SEIS, DOE calculated these statistical measures for 300 epistemic realizations at each time step of the projected annual individual dose histories. The plot of the mean represents the average of all 300 data points at each time step. For each point on the plot of the median dose, 50 percent of the data have a value greater than the plotted point and 50 percent have a value less than the plotted point. Similarly, for the 5th- and 95th-percentiles, the plotted data points are such that 95 percent of data are greater than the plotted point and 5 percent of the data points are greater than the plotted points, respectively, for each time step.

F.4.1 IMPACTS FROM REPOSITORY PERFORMANCE IN THE ABSENCE OF DISRUPTIVE EVENTS

This section discusses repository performance in the absence of seismic and igneous activity. It examines two scenario classes—Nominal Scenario Class and Early Failure Scenario Class. In this section and subsequent sections, impacts from repository performance are described using annual dose histories that illustrate the mean and median annual doses calculated for the different modeling cases. In addition, dose histories of major radionuclides that contribute to the estimate of mean annual dose are also presented. These latter time histories illustrate the important radionuclides that contribute to mean annual dose and generally are typical of key radionuclides that contribute to median dose.

F.4.1.1 Nominal Scenario Class

The Nominal Scenario Class for the TSPA-SEIS model includes the features, events, and processes relevant to the natural evolution and degradation of the repository system, but excludes those features, events, and processes for the Early Failure, Igneous, and Seismic Scenario Classes. More specifically, the Nominal Scenario Class includes features, events, and processes for waste package and drip shield degradation as a function of expected corrosion processes (for example, general corrosion, stress corrosion cracking, and seepage-induced localized corrosion) that the hydrologic and geochemical environments, which would vary with time, would induce. This class also includes the important effects and system perturbations due to climate change and repository heating, which would occur after repository closure. DOE modeled the failure of the waste packages and drip shields, degradation of the waste forms, mobilization of radionuclides, and subsequent release from the engineered barrier system. The Nominal Scenario Class includes migration of radionuclides by groundwater that would percolate through the unsaturated zone to the saturated zone and then travel to the accessible environment.

Figure F-3 shows the projected annual dose results of 300 probabilistic simulations for the Nominal Scenario Class Modeling Case at the RMEI location [about 18 kilometers (11 miles) downgradient from the proposed repository] for the post-10,000-year period. The mean, median, and 5th- and 95th-percentile curves in Figure F-3 show uncertainty in the value of the projected annual dose, with consideration of epistemic uncertainty from incomplete knowledge of the behavior of the physical system.

The results for this modeling case show zero mean annual dose for the first 10,000 years because no waste packages are estimated to fail (by general corrosion, localized corrosion, or stress corrosion cracking) in this period. The first waste package failure (by nominal stress corrosion cracking) would occur at approximately 100,000 years, and the drip shields would begin to fail by general corrosion at approximately 260,000 years. As shown in Figure F-3, the projected mean and median annual doses are 0.5 and 0.3 millirem, respectively, for the post-10,000-year period. Figure F-4 shows the radionuclides that dominate the projected mean annual dose for the Nominal Scenario Case. The main contributors to mean annual dose would be the highly soluble and mobile radionuclides iodine-129 and technetium-99.

F.4.1.2 Early Failure Scenario Class

The Early Failure Scenario Class includes features, events, and processes that relate to early waste package and drip shield failure due to manufacturing, material defects, or preemplacement operations that would include improper heat treatment. In addition, this scenario class includes all features, events, and processes in the Nominal Scenario Class. As in the Nominal Scenario Class, failure of the waste

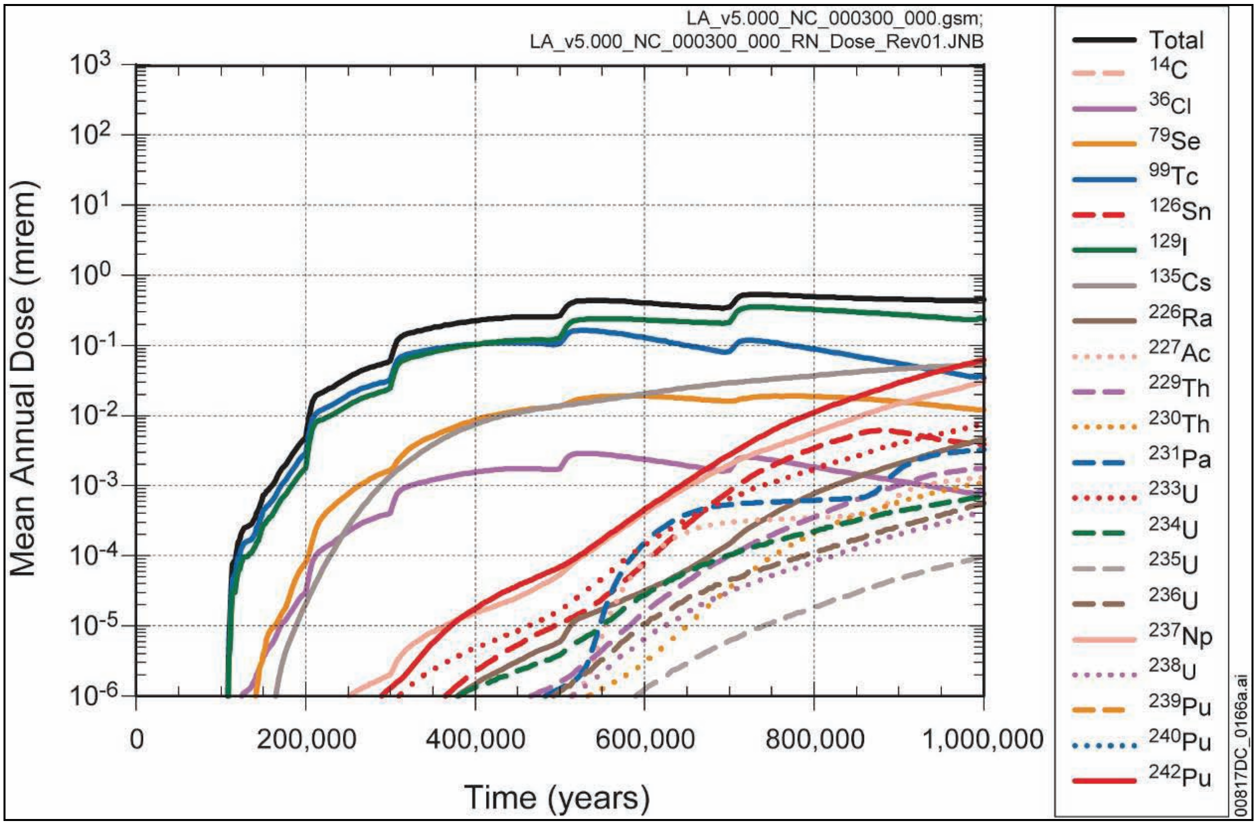

Figure F-4. Mean annual dose histories of major radionuclides for the Nominal Scenario Class Modeling Case for the post-10,000-year period.

packages and drip shields would ultimately lead to waste form exposure to water and mobilization and eventual release of radionuclides from the repository. Groundwater percolation through the unsaturated zone would transport the radionuclides to the saturated zone and then to the accessible environment by water flow in the saturated zone. Section F.2.4 describes the analysis of drip shield and waste package early failures in the TSPA-SEIS model.

DOE evaluated two modeling cases for this scenario class—Drip Shield Early Failure and Waste Package Early Failure. The following sections describe these modeling cases.

F.4.1.2.1 *Drip Shield Early Failure Modeling Case*

The analysis for this modeling case assumed that the defective drip shields would fail at the time of repository closure. It also assumed that waste packages under these defective drip shields would fail early. (The Nominal Scenario Class Modeling Case does not include these unexpected conditions.) Figure F-5 shows the performance assessment calculations of the annual dose histories; the plot shows projections for annual dose for the first 10,000 years after closure and the post-10,000-year period. The estimated doses account for aleatory uncertainty for characteristics of the early failed drip shields such as the number of early failed drip shields, types of waste package under failed drip shields, and their locations in the repository. The mean, median, and 5th- and 95th-percentile curves in this plot show the uncertainty in the magnitude of the projected annual dose, which reflects the epistemic uncertainty from incomplete knowledge of the behavior of the physical system. The calculations for the first 10,000-years give a projected mean annual dose of approximately 0.0003 millirem estimated to occur at approximately 2,000 years. The projected annual doses decline thereafter and drop to less than 0.0003 millirem for the post-10,000 year period.

Figure F-6 shows the radionuclides that would contribute most to the total mean annual dose for the Drip Shield Early Failure Modeling Case. In the first 2,000 years after repository closure, soluble and mobile radionuclides, in particular technetium-99, iodine-129, and carbon-14 would be the primary contributors to the mean annual dose. During the post-10,000-year period, the radionuclides plutonium-239, plutonium-240, and neptunium-237 would dominate the mean annual dose.

F.4.1.2.2 *Waste Package Early Failure Modeling Case*

This modeling case assumes that the defective waste packages would fail at the time of repository closure. However, it assumes that the drip shields would degrade by general corrosion and fail in accordance with the Nominal Scenario Class Modeling Case. Figure F-7 shows the annual dose histories for this modeling case for the first 10,000 years after closure and post-10,000-year period. The projected dose accounts for aleatory uncertainty for characteristics of the early failed waste packages such as the number of early failed waste packages, types of early failed waste packages, and their locations in the repository. The mean, median, and 5th- and 95th-percentile curves in Figure F-7 show uncertainty in the value of the projected annual dose, with consideration of epistemic uncertainty from incomplete knowledge of the behavior of the physical system.

For the first 10,000-years after repository closure, the projected mean annual dose is about 0.004 millirem and would occur at about 9,800 years. Annual doses would increase after the climate changed at 10,000 years. The projected mean and median annual doses reach levels of about 0.2 and 0.006 millirem, respectively, before 15,000 years and gradually decline thereafter.

Figure F-8 shows the projected mean annual dose from the radionuclides that would contribute most to the total mean annual dose for the Waste Package Early Failure Modeling Case. In the first 10,000 years after closure, more soluble and mobile radionuclides, in particular technetium-99, iodine-129, and carbon-14, would dominate the estimate of mean annual dose. During the post-10,000-year period, the mobile radionuclides technetium-99, iodine-129, and carbon-14 are projected to dominate the annual dose.

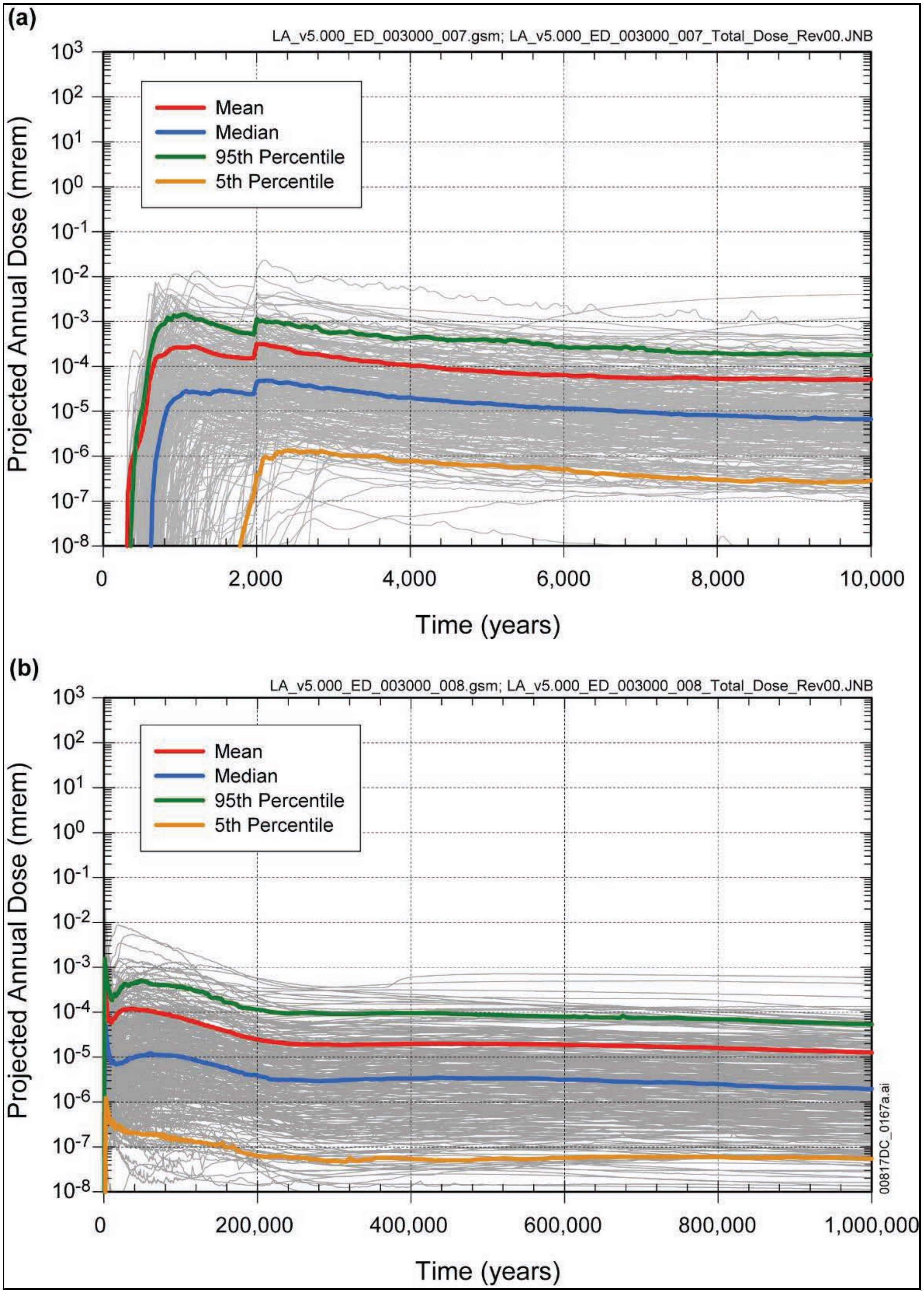

Figure F-5. Projected annual dose for the Drip Shield Early Failure Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

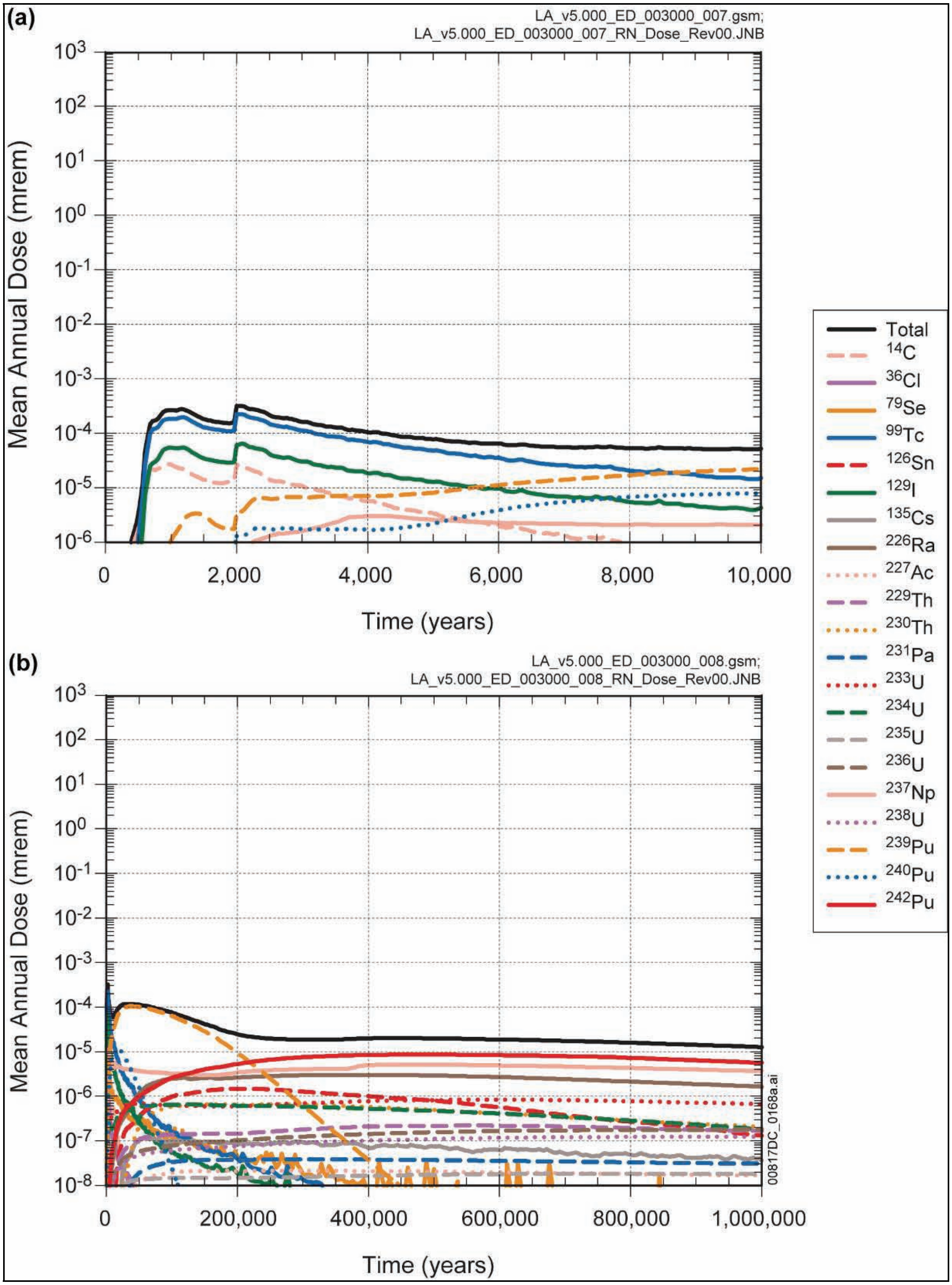

Figure F-6. Mean annual dose histories of major radionuclides for the Drip Shield Early Failure Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

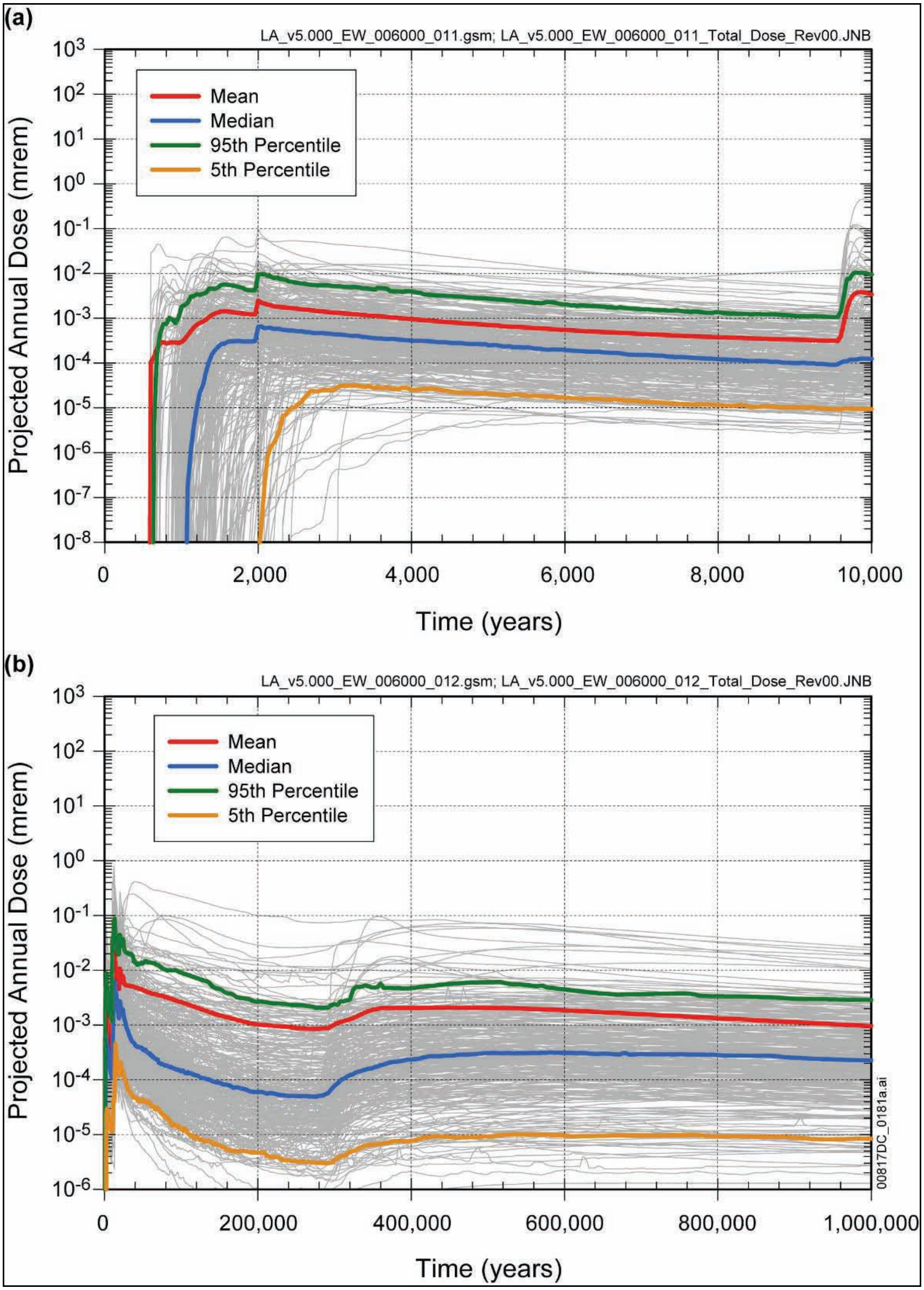

Figure F-7. Projected annual dose for the Waste Package Early Failure Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

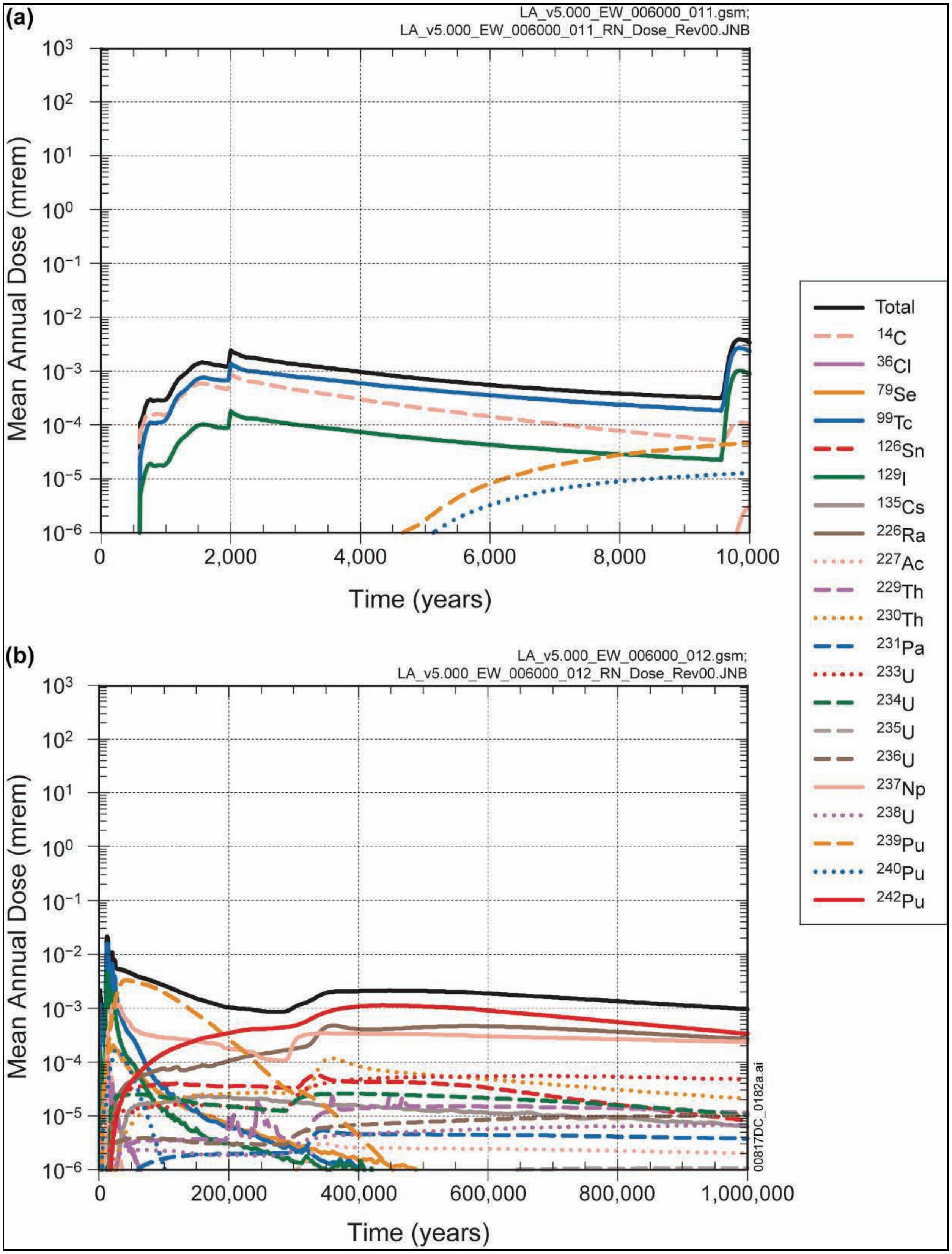

Figure F-8. Mean annual dose histories of major radionuclides for the Waste Package Early Failure Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

F.4.2 IMPACTS FROM DISRUPTIVE EVENTS

This section discusses disruptive events that include those due to seismic and igneous activity. Chapter 5, Section 5.8 discusses inadvertent intrusion into the repository by a drilling crew.

F.4.2.1 Igneous Scenario Class

The Igneous Scenario Class describes the performance of the repository system in the event of igneous activity that would disrupt the repository. This class includes all features, events, and processes in the Nominal Scenario Class. In addition, it includes the set of features, events, and processes specific to igneous disruption. The Igneous Scenario Class consists of two modeling cases: (1) the Igneous Intrusion Modeling Case that represents the interaction of an intrusive magma dike into the repository and subsequent release of radionuclides to the groundwater pathway, and (2) the Volcanic Eruption Modeling Case that represents a hypothetical volcanic eruption through the repository that would emerge at the land surface and cause releases of radionuclides to the atmospheric pathway.

F.4.2.1.1 *Igneous Intrusion Modeling Case*

In this modeling case, a magmatic dike would intersect the footprint of the repository. Radionuclide release and transport away from the repository would be similar to the Nominal Modeling Case for radionuclide release and transport (Chapter 5, Section 5.5), but this case included the intrusion. There are two main components to the model—the behavior of the waste packages and other engineered barrier system elements damaged by an igneous intrusion, and groundwater flow and radionuclide transport away from the waste packages. The modeling case conservatively assumed that all of the drip shields and waste packages in the repository would be damaged, which would expose the waste forms to percolating groundwater with subsequent degradation, radionuclide mobilization, and transport.

Radionuclide transport would occur through the invert into the unsaturated zone, depending on solubility limits and the rate of water flux through the intruded drifts. The modeling case conservatively assumed that the drifts would not act as a capillary barrier and the seepage water flux into a magma-intruded drift would be equal to the percolation flux in the overlying host rock. It took no credit for water diversion by the remnants of the drip shield, waste package, or cladding. Actual thermal, chemical, hydrological, and mechanical conditions in the drift after igneous intrusion are unknowable, but a conservative assumption that the engineered barriers completely failed would be sufficient to compensate for the uncertainty about drift conditions.

Figure F-9 shows projected annual dose histories for the Igneous Intrusion Modeling Case for the first 10,000 years after closure and post-10,000-year period. The projected dose accounts for aleatory uncertainty for characteristics of the igneous intrusion such as the number of future events and the time at which they occurred. The mean, median, and 5th- and 95th-percentile curves in Figure F-9 show uncertainty in the value of the projected annual dose, with consideration of epistemic uncertainty from incomplete knowledge of the behavior of the physical system during and after the disruptive event. These figures show that the mean projected dose for 10,000 years after closure is less than 0.06 millirem and for the post-10,000-year period is about 1.3 millirem. The median projected annual dose for the post-10,000-year period is less than 0.4 millirem.

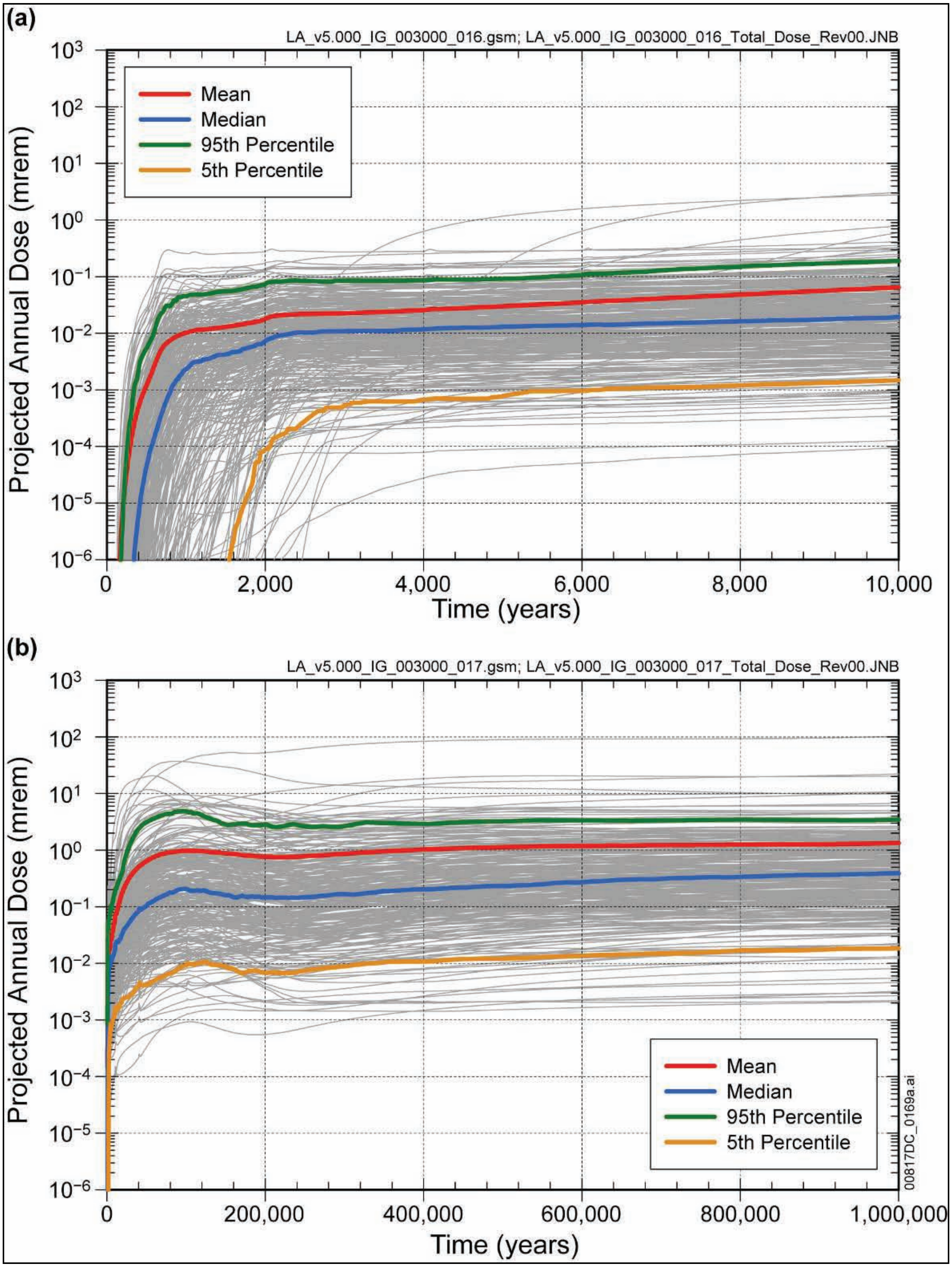

Figure F-9. Projected annual dose for the Igneous Intrusion Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

The results in Figure F-10 show the radionuclides that would contribute most to the estimate of mean projected dose for the Igneous Intrusion Modeling Case. Figure F-10a shows that technetium-99 and iodine-129 would dominate the estimate of the mean for the first 4,000 years and plutonium-239, technetium-99, and plutonium-240 would dominate the estimate of the mean for the 10,000-year postclosure period. Figure F-10b shows that plutonium-239 in both dissolved and colloidal forms would dominate the estimate of the mean for the next 170,000 years, and radium-226, plutonium-242, and neptunium-237 would dominate the estimate of the mean for the remainder of the post-10,000-year period.

F.4.2.1.2 *Volcanic Eruption Modeling Case*

The conceptualization of a volcanic eruption at Yucca Mountain envisioned an igneous dike that would rise through the Earth's crust and intersect one or more repository drifts. An eruptive conduit could form somewhere along the dike as it neared the surface and fed a volcano. Waste packages in the direct path of the conduit would be destroyed, and the waste in those packages would be entrained in the eruption. Volcanic ash would be contaminated, erupted, and transported by wind. Ash would settle out of the plume as it was transported downwind, which would result in an ash layer on the land surface. Members of the public would receive a radiation dose from exposure pathways for the contaminated ash layer.

Model development included the incorporation of conservative assumptions about the event, selection of input parameter distributions that characterize important physical properties of the system, and use of a computational model to calculate entrainment of waste in the erupting ash. Each intrusive event (a swarm of one or more dikes) could generate one or more volcanoes somewhere along its length, but eruptions would not have to occur in the repository footprint. Approximately 77 percent of intrusive events that intersected the repository would be due to one or more surface eruptions in the repository footprint. The number of eruptive conduits (volcanoes) would be independent of the number of dikes in a swarm. The analysis included characteristics of the eruption such as eruptive power, style (violent or normal), velocity, duration, column height, and total volume of erupted material.

Figure F-11 shows an estimate of the uncertainty in the projected dose for the volcanic eruption modeling case for first 10,000 years after closure and post-10,000-year period. The projected dose considers aleatory uncertainty for characteristics of the eruption such as number of waste packages intersected by the eruption, the fraction of waste packages intersected that are ejected, eruption power, wind direction, and wind speed. The mean, median, and 5th- and 95th-percentile curves in Figure F-11 show uncertainty in the value of the projected annual dose, and consider epistemic uncertainty from incomplete knowledge of the behavior of the physical system during and after the disruptive event. These figures show that the mean projected dose for 10,000 years after closure is less than 0.0002 millirem and that for the post-10,000-year period is less than 0.0002 millirem. The median projected annual dose is less than 0.0001 millirem for the post-10,000-year period.

Figure F-12 shows the radionuclides that dominate the estimate of mean annual dose. Because transport of radionuclides to the location of the RMEI would be more rapid in the Volcanic Eruption Modeling Case than in the Igneous Intrusion Modeling Case, short-lived radionuclides would contribute to the estimate of the mean annual dose estimate. Figure F-12 shows that short-lived radionuclides (for example, cesium-137 and plutonium-238) would be significant contributors at early times, but their contributions would drop rapidly because of radioactive decay. At 300 years, americium-241 would dominate the total, but its contribution would diminish rapidly after about 1,000 years, also due to decay.

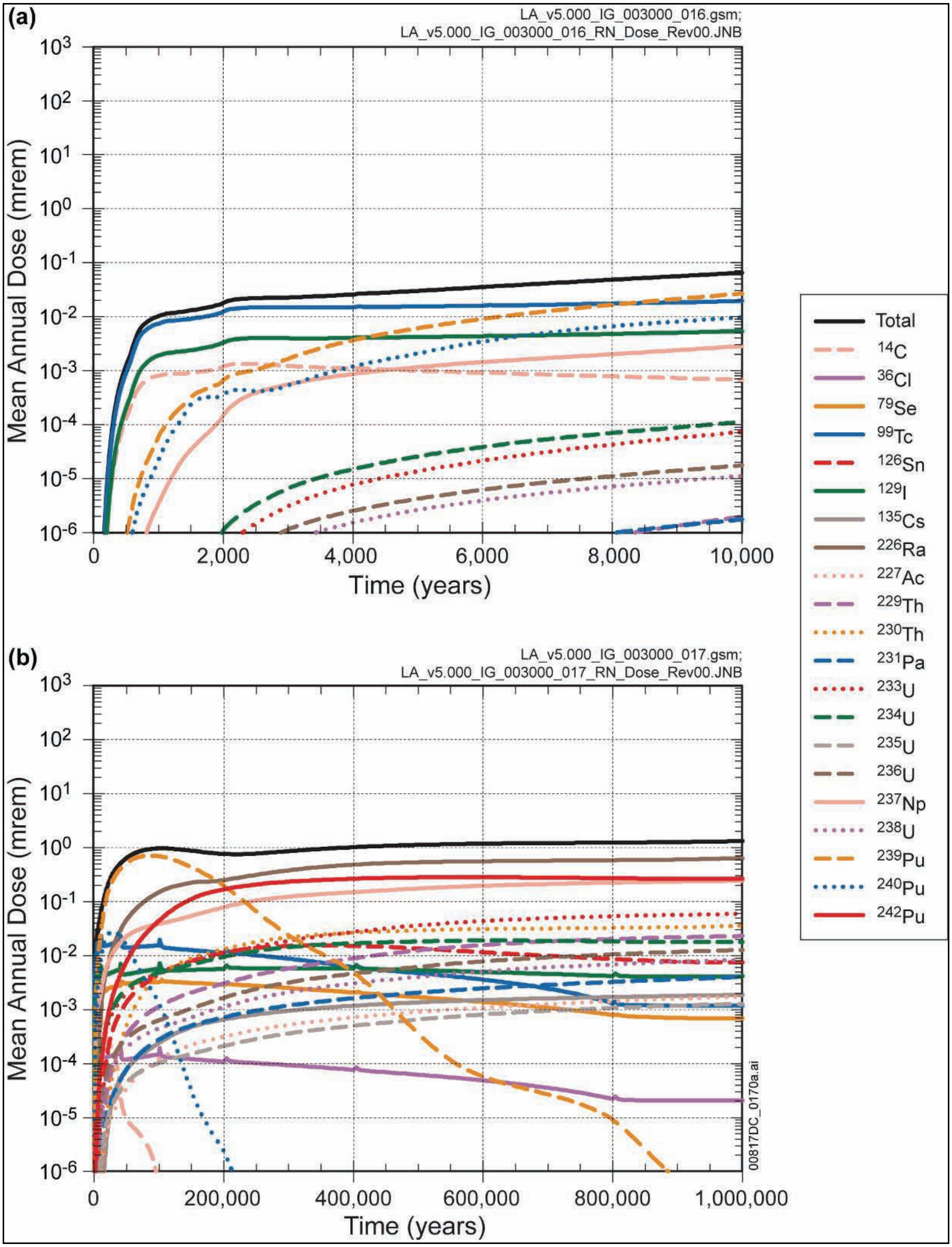

Figure F-10. Mean annual dose histories of major radionuclides for (a) the Igneous Intrusion Modeling Case for the first 10,000 years after repository closure and (b) post-10,000-year period.

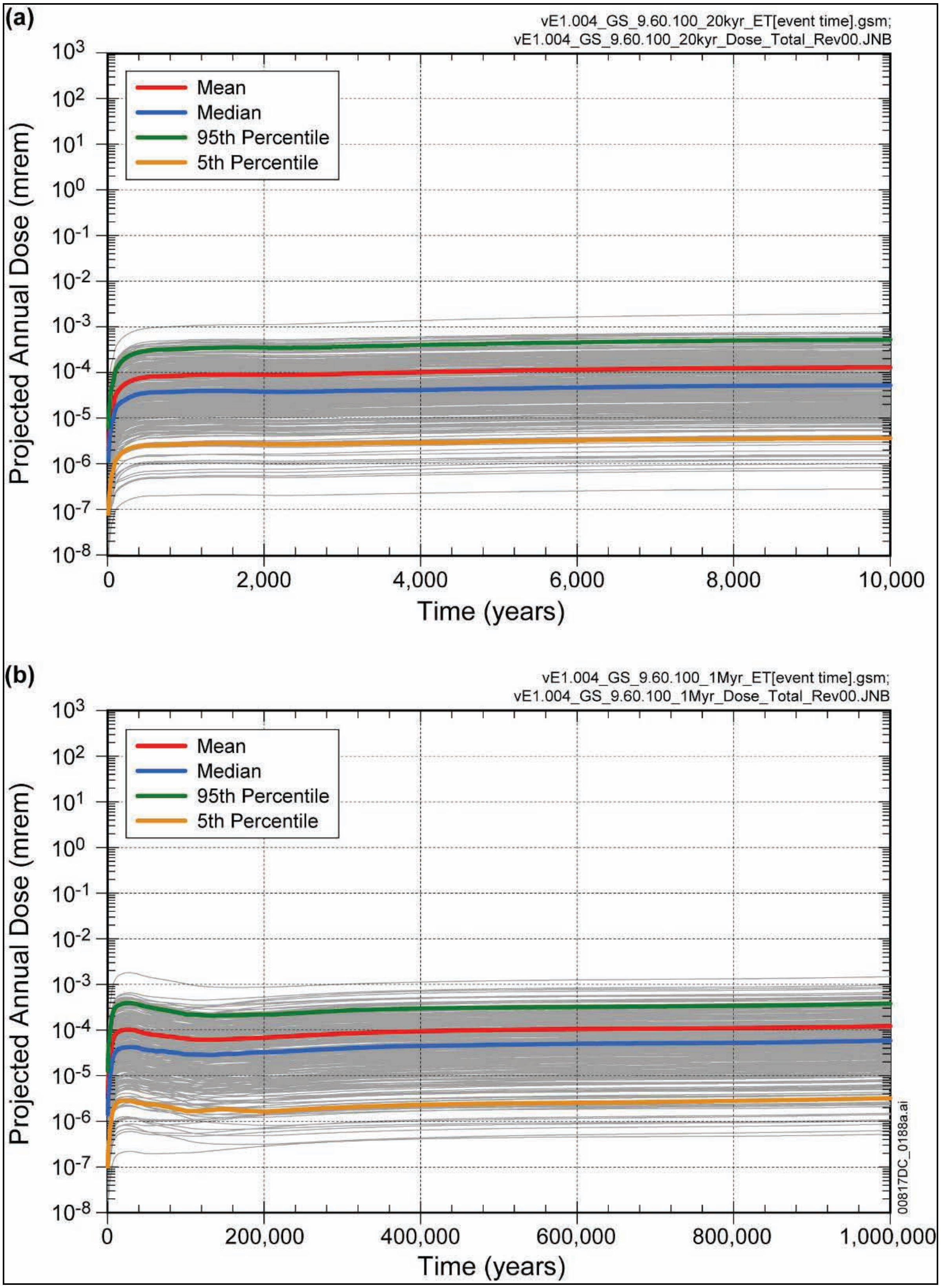

Figure F-11. Projected annual dose for the Volcanic Eruption Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

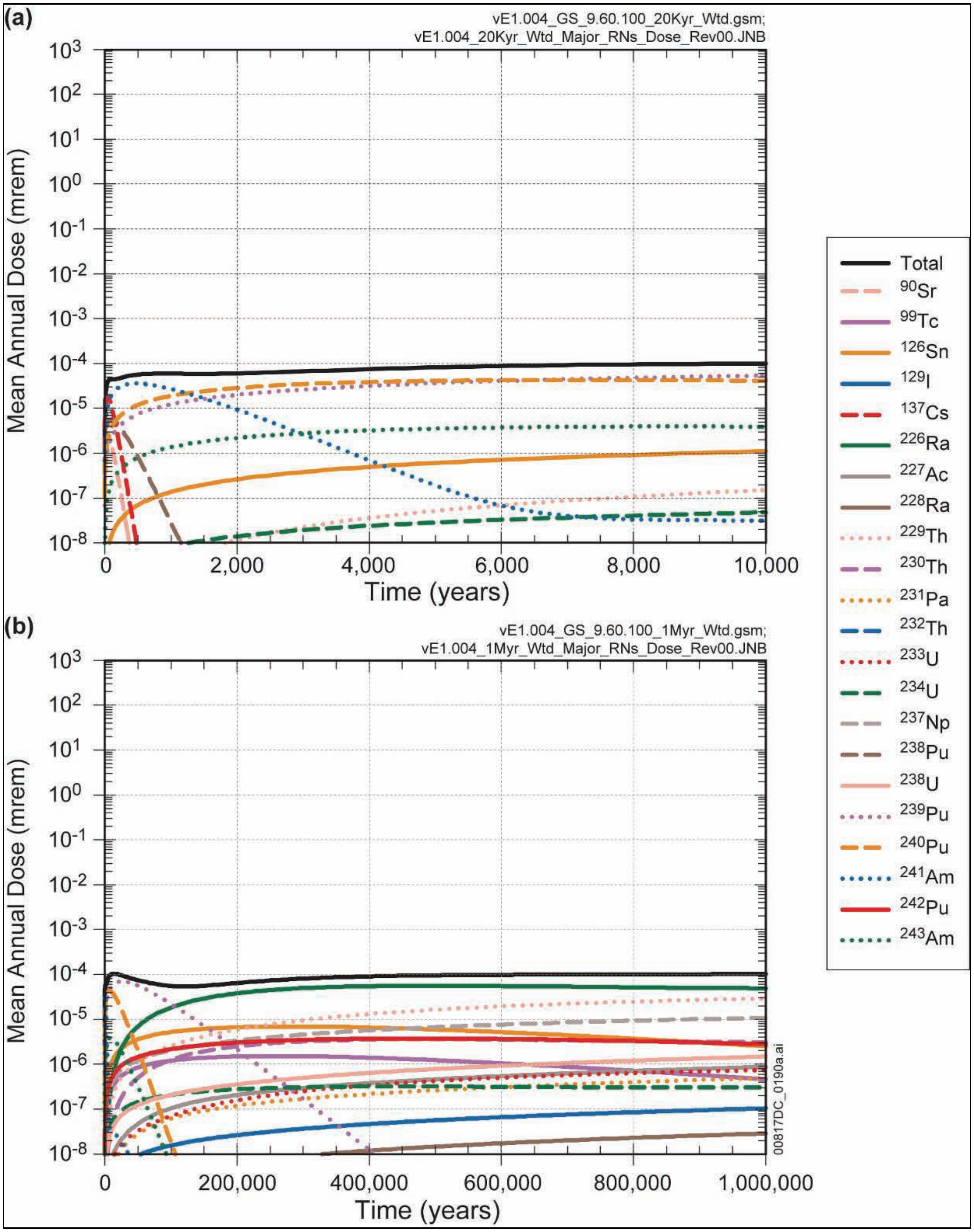

Figure F-12. Mean annual dose histories of major radionuclides for the Volcanic Eruption Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

These short-lived radionuclides would be able to reach the location of the RMEI before they decayed because atmospheric transport to this location would be relatively rapid. After 1,000 years, plutonium-239 and -240 would become dominant contributors until approximately 100,000 years after closure when radium-226 and thorium-229 became the primary dose contributors for the remainder of the post-10,000-year period.

F.4.2.2 Seismic Scenario Class

The Seismic Scenario Class describes future performance of the repository system in the event of seismic activity that could disrupt the repository system. The Seismic Scenario Class represents the direct effects of vibratory ground motion and fault displacement associated with seismic activity. Indirect effects of drift collapse are also considered in this Scenario Class. The Seismic Scenario Class considers the effects of the seismic hazards on drip shields and waste packages. The Seismic Scenario Class also takes into account changes in seepage, waste package degradation, and flow in the engineered barrier system that might be associated with a seismic event. The conceptual models and abstractions for the mechanical response of engineered barrier system components to seismic hazards at a geologic repository are summarized in *Seismic Consequence Abstraction* (DIRS 176828-SNL 2007, all).

The Seismic Scenario Class estimates the mean annual dose due to a presumed seismic event and takes into account the relevant processes that come into play and affect system performance. The Seismic Scenario Class is represented by two modeling cases, the Seismic Ground Motion Modeling Case and the Seismic Fault Displacement Modeling Case.

F.4.2.2.1 *Seismic Ground Motion Modeling Case*

The first modeling case represents drip shields and waste packages that fail from mechanical damage associated with seismic vibratory ground motion. This modeling case is referred to as the Seismic Ground Motion Modeling Case. The Seismic Ground Motion Modeling Case includes the following degradation mechanisms on the drip shields and waste packages: stress corrosion cracking, tearing or rupture, localized corrosion, and collapse of drip shield supports. Figure F-13 presents projected annual dose histories for the Seismic Ground Motion Modeling Case for the first 10,000 years after closure and the post-10,000-year period. The projected dose takes into account aleatory uncertainty associated with characteristics of future events such as number of events, times of events, and event's peak ground velocity.

The mean, median, and 5th- and 95th-percentile curves on Figure F-13 show uncertainty in the value of the projected annual dose and consider epistemic uncertainty due to incomplete knowledge of the behavior of the physical system during and after the disruptive event. These figures show that the mean projected annual dose for 10,000 years after closure is approximately 0.2 millirem and for the post-10,000-year period is approximately 1.5 millirem. The median projected dose for the post-10,000-year period is less than 0.5 millirem. The spikes in the results correspond to the occurrence of seismic events of sufficient magnitude to cause damage to the waste packages. These spikes occur in each realization at the same time because each epistemic realization has essentially the same set of future conditions. That is, each epistemic realization has the same number of events, the same event times, and the same event magnitudes. As a result, all epistemic realizations and their spikes reinforce each other in the calculation of the mean and median annual doses and cause the spikes to become more pronounced.

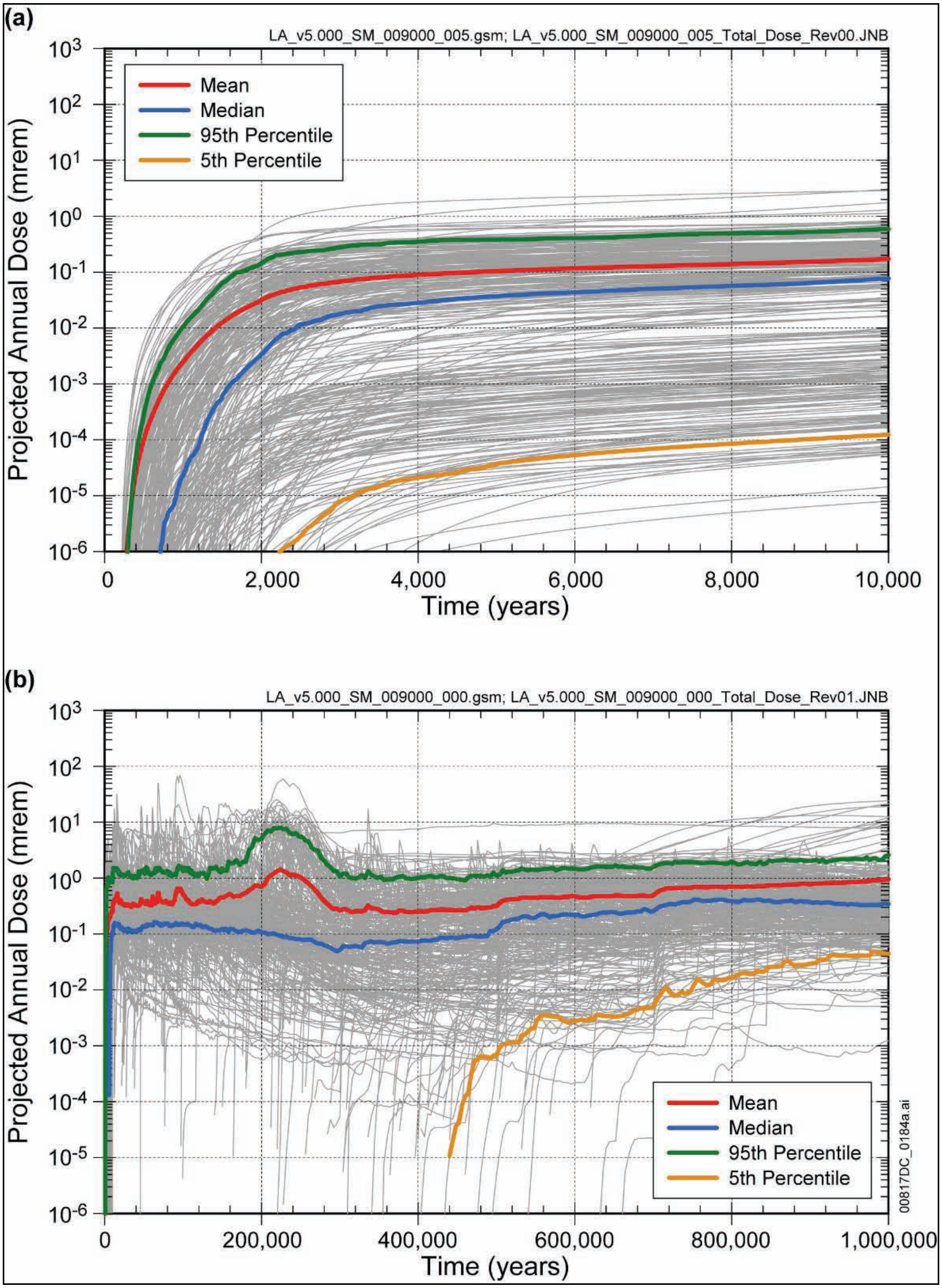

Figure F-13. Projected annual dose for the Seismic Ground Motion Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

The results in Figure F-14 show the radionuclides that would contribute most to the estimate of mean projected annual dose for the Seismic Ground Motion Case. Figure F-14a shows that technetium-99, carbon-14, and iodine-129 would dominate the estimate of the mean for 10,000 years after closure. Figure F-14b shows that radionuclides technetium-99, iodine-129, selenium-79, and plutonium-239 would dominate the estimate of the mean for the post-10,000-year period up to about 250,000 years. Plutonium-242, iodine-129, and neptunium-237 become dominant radionuclides later in time. The influence of carbon-14 would decrease completely by 100,000 years because of radioactive decay. The codisposal waste packages would be the primary waste packages damaged during 10,000 years after closure because the commercial spent nuclear fuel waste packages would be much stronger and more failure-resistant. The commercial spent nuclear fuel waste packages would be more robust than codisposal waste packages because they include two inner stainless-steel vessels instead of one; the inner vessel and its lids similar to the codisposal waste packages, and an additional stainless-steel TAD canister. The predominant mechanism that would cause damage to codisposal and commercial spent nuclear fuel waste packages would be small cracks (stress-corrosion cracking) that resulted in releases from the waste packages by diffusion. Diffusive transport of dissolved radionuclides through the cracks would be sufficiently high that these radionuclides would contribute significantly to the total mean projected annual dose.

F.4.2.2.2 *Seismic Fault Displacement Modeling Case*

The Seismic Fault Displacement Modeling Case includes disruption of waste packages and drip shields by the displacement of faults, as well as local corrosion failure of waste packages onto which water would flow through drip shield breaches.

Figure F-15 shows the projected annual dose histories for the Seismic Fault Displacement Modeling Case for the first 10,000 years after closure and post-10,000-year period. The projected dose accounts for aleatory uncertainty for characteristics for the number of disrupted drip shields and waste packages. The mean, median, and 5th- and 95th-percentile curves on Figure F-15 show uncertainty in the value of the projected annual dose, taking into account epistemic uncertainty from incomplete knowledge of the behavior of the physical system during and after the disruptive event. These figures show that the mean projected annual dose for 10,000 years after closure is less than 0.002 millirem and for the post-10,000-year period would be approximately 0.02 millirem. The median projected dose for the post-10,000-year period is approximately 0.01 millirem.

The results in Figure F-16 show the radionuclides that contribute most to the estimate of mean projected annual dose. Figure F-16a shows that plutonium-239, iodine-129, and plutonium-240 would dominate the estimate of the mean projected annual dose for 10,000 years after closure. Figure F-16b shows that plutonium-239, radium-226, and technicium-99 would dominate the mean at 100,000 years and plutonium-242, radium-226, and neptunium-237 would dominate the mean for the remainder of the post-10,000-year period.

F.4.3 TOTAL IMPACTS FROM ALL SCENARIO CLASSES

DOE evaluated the total impacts of postclosure repository performance by summing the annual projected doses histories for each modeling case. The result is the total projected annual dose to the RMEI from the waste packages that would fail in the Nominal, Early Failure, Igneous, and Seismic Scenario Classes.

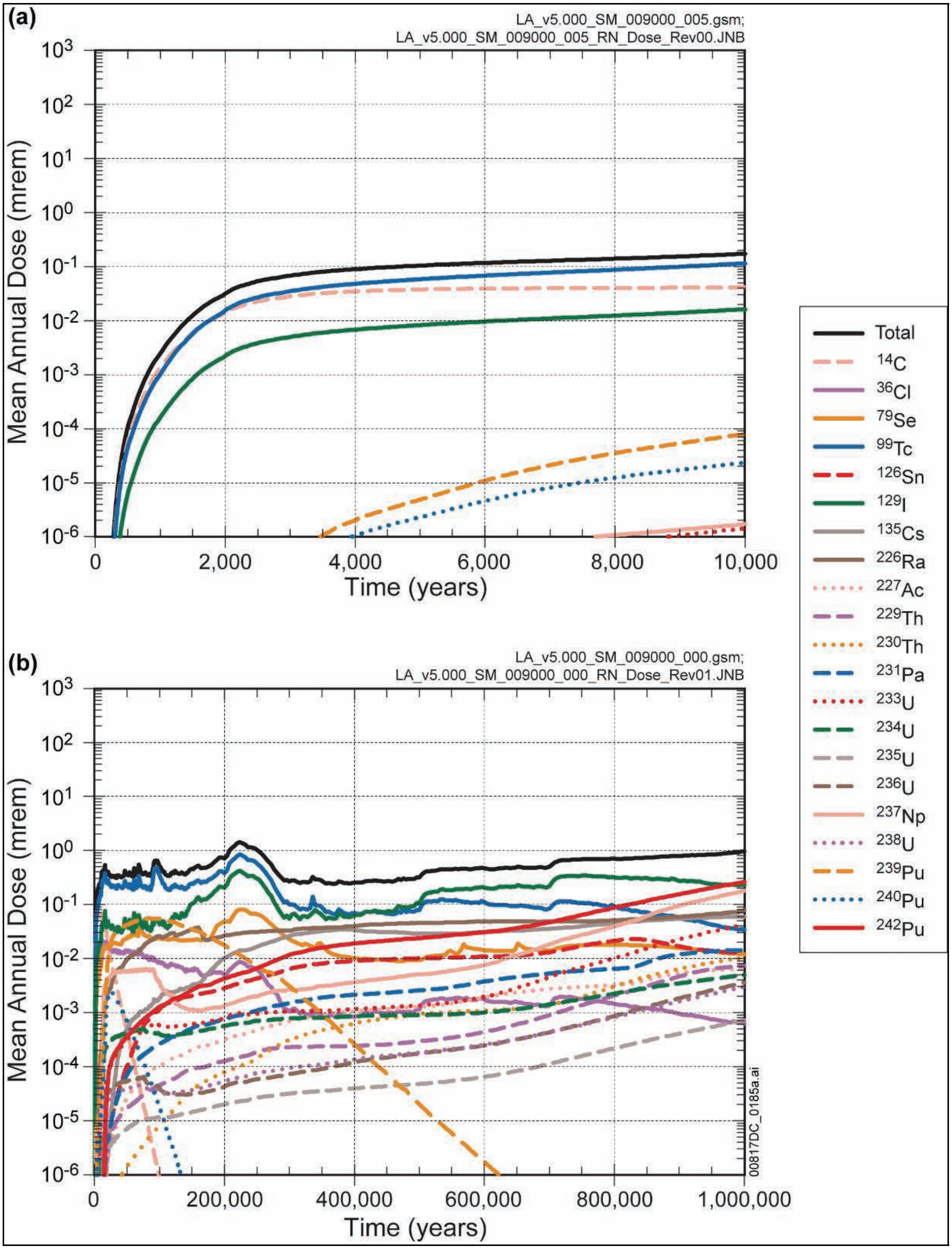

Figure F-14. Mean annual dose histories of major radionuclides for the Seismic Ground Motion Modeling Case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

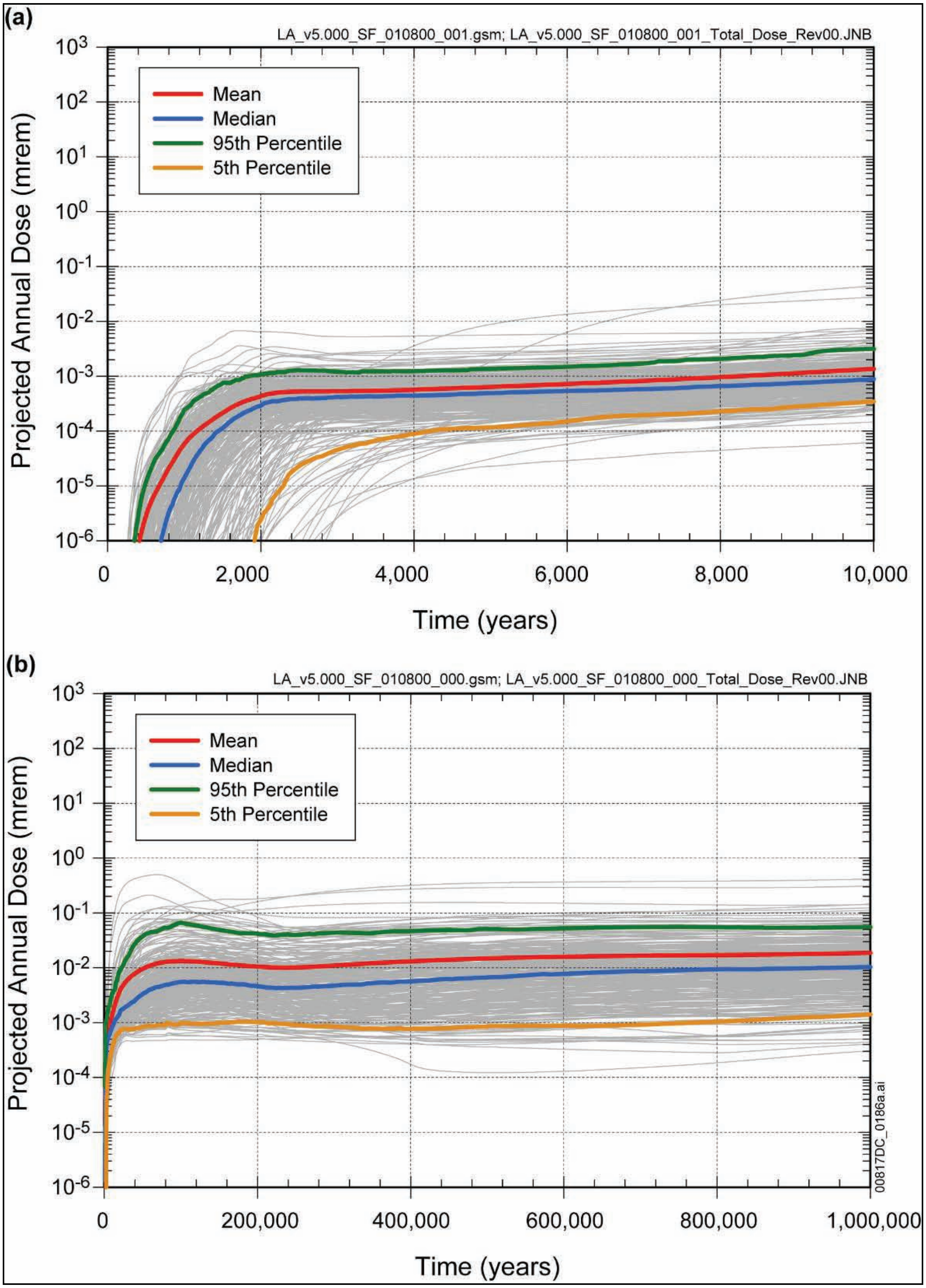

Figure F-15. Projected annual dose for the Seismic Fault Displacement Modeling Case for the first 10,000 years after repository closure and post-10,000-year period.

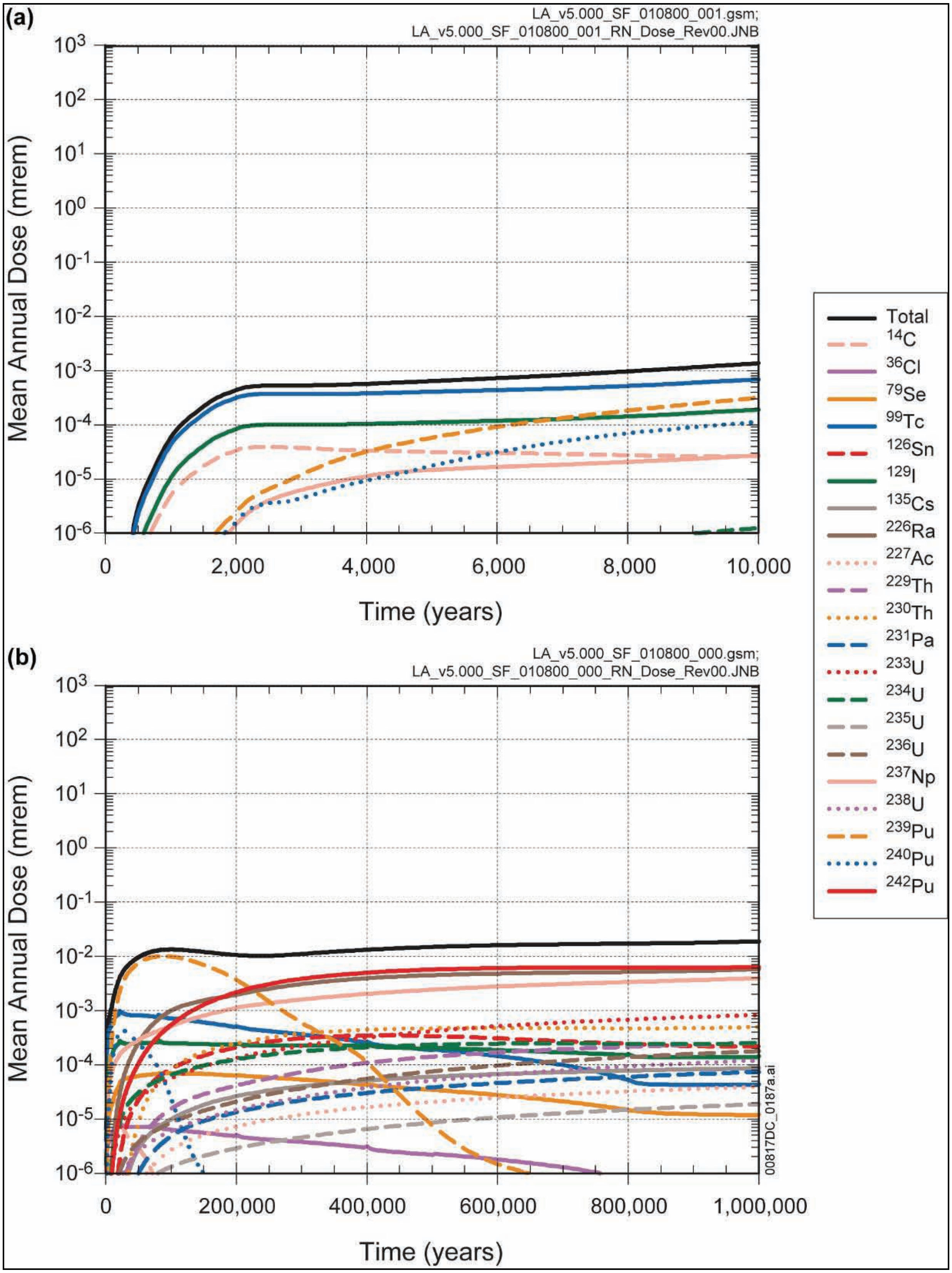

Figure F-16. Mean annual dose histories of major radionuclides for the Seismic Fault Displacement Modeling Case for the first 10,000 years after repository closure and post-10,000-year period.

Equation F-1 represents the distribution for total expected annual dose $\overline{D}_T(\tau, \boldsymbol{e_i})$ as a function of time τ:

$$\overline{D}_T(\tau, \boldsymbol{e_i}) = \overline{D}_N(\tau, \boldsymbol{e_i}) + \overline{D}_{EF}(\tau, \boldsymbol{e_i}) + \overline{D}_I(\tau, \boldsymbol{e_i}) + \overline{D}_S(\tau, \boldsymbol{e_i}) \qquad \text{(Equation F-1)}$$

where e_i denotes a realization or sampling of epistemic uncertainty *i* (Chapter 5, Section 5.3.4.2.1) and *i = 1, 2,…*. The quantity $\overline{D}_N(\tau, \boldsymbol{e_i})$ is the expected annual dose resulting from nominal processes, and quantities $\overline{D}_{EF}(\tau, \boldsymbol{e_i})$, $\overline{D}_I(\tau, \boldsymbol{e_i})$, and $\overline{D}_S(\tau, \boldsymbol{e_i})$ are the expected values of annual dose resulting from the occurrence of early failure, igneous and seismic events, respectively.

Equation F-1 shows the calculation of total mean annual dose as the sum of mean annual dose for each scenario class. In turn, the mean annual dose for each scenario class is the sum of mean annual doses for the modeling cases comprising the scenario class, with the exception of the Seismic Scenario Class. The Nominal and Seismic Scenario Classes were combined for the calculation of dose during the post-10,000-year period because the nominal processes of corrosion affect the susceptibility of the engineered barrier to damage from seismic events. For the post-10,000-year, the expected annual dose for the Nominal and the Seismic Scenario Classes are combined, and are computed as:

$$\overline{D}_N(\tau, \boldsymbol{e_i}) + \overline{D}_S(\tau, \boldsymbol{e_i}) = \overline{D}_{GM}(\tau, \boldsymbol{e_i}) + \overline{D}_{FD}(\tau, \boldsymbol{e_i}) \qquad \text{(Equation F-2)}$$

where $\overline{D}_{GM}(\tau, \boldsymbol{e_i})$ is the expected annual dose from seismic ground motion events and $\overline{D}_{FD}(\tau, \boldsymbol{e_i})$ is the expected annual dose from seismic fault displacement events.

Figures 5-4 and 5-6 (Chapter 5, Section 5.5) show representations of the epistemic distributions for $\overline{D}_T(\tau, \boldsymbol{e_i})$ for the first 10,000 years and the post-10,000-year period, respectively, where each individual dose curve or history in the figures corresponds to expected time histories over aleatory uncertainty. The mean and median histories derive directly from this distribution, as shown on the figures. For example, the total mean annual dose, $\overline{\overline{D}}_T(\tau)$, is calculated as the expected value of $\overline{D}_T(\tau, \boldsymbol{e_i})$ as given by Equation F-3:

$$\overline{\overline{D}}_T(\tau) \cong \frac{1}{N}\sum_{i=1}^{N} \overline{D}_T(\tau, \boldsymbol{e_i}) \qquad \text{(Equation F-3)}$$

This approach does not enable the display of uncertainty, but it illustrates the important modeling case contributors to the total mean annual dose. Figure F-17 shows the total mean annual dose and the median annual dose contributions from each modeling case. The contribution to total annual dose from the Nominal Scenario Modeling Case is included in the Seismic Ground Motion Modeling Case and therefore is not shown separately in this figure. The figure shows that for the first 10,000 years after closure (Figure F-17a) and post-10,000-year period (Figure F-17b) the Seismic Ground Motion and Igneous Intrusion Modeling Cases, respectively, would provide the largest contributions to the total annual dose. *Total System Performance Assessment Model/Analysis for the License Application* (DIRS 182846-SNL 2007, Section 6.1) provides the details for the development of Equation F-1, the distribution for $D_T(\tau, \boldsymbol{e_i})$, and the calculation of the mean and median total annual doses.

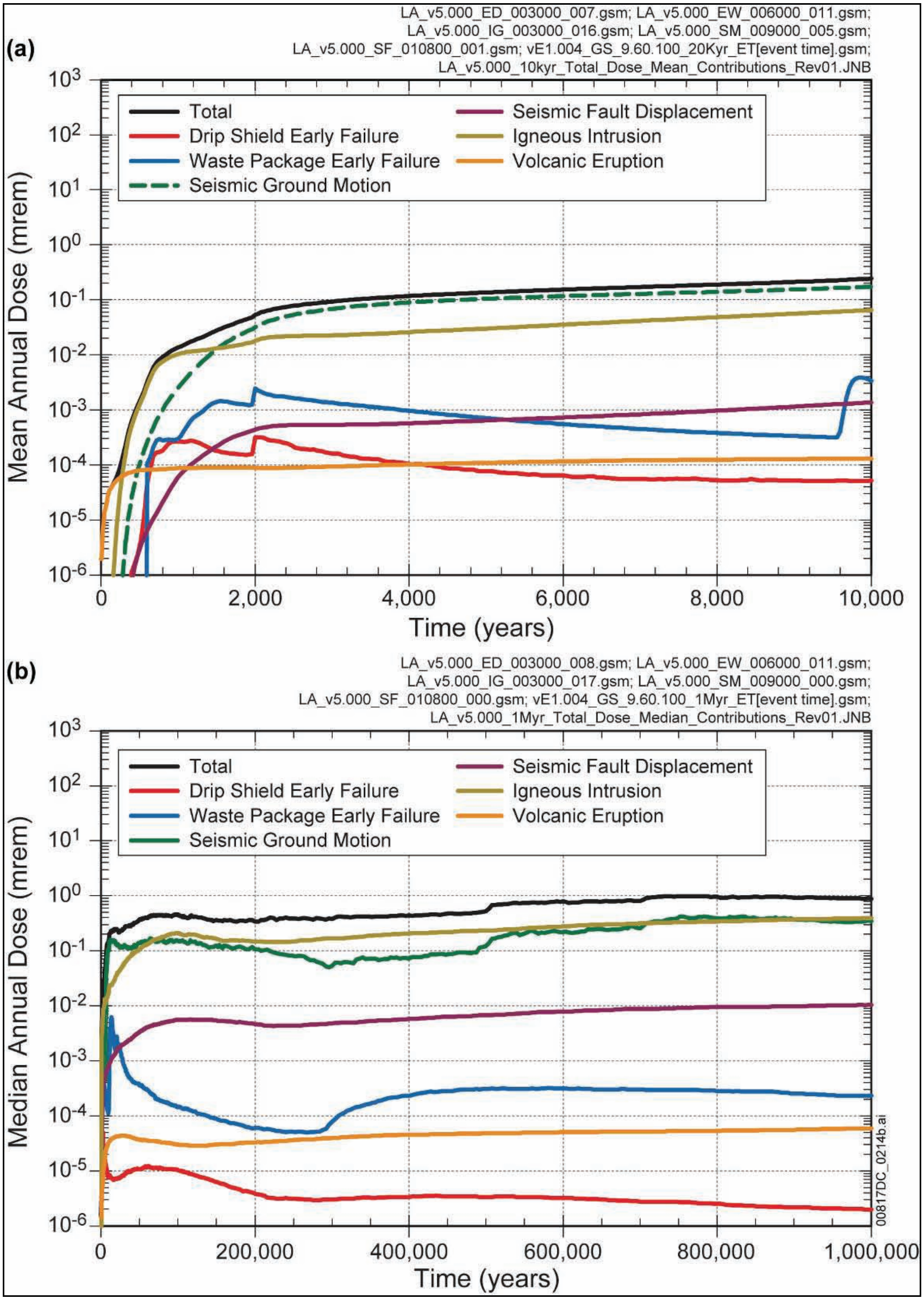

Figure F-17. Total mean annual dose and median annual doses for each modeling case for (a) the first 10,000 years after repository closure and (b) post-10,000-year period.

F.4.4 COMPARISON TO GROUNDWATER PROTECTION STANDARDS

DOE excluded unlikely natural processes and events from the performance calculations to evaluate conformance with groundwater protection, as required by the EPA rule (40 CFR 197.30 and 197.31). The standards require compliance with three groundwater protection performance measures:

1. Maximum annual concentration of radium-226 and -228 in a representative volume of 3.7 million cubic meters (3,000 acre-feet) of groundwater.

2. Gross alpha activity (excluding radon and uranium) in the representative volume of groundwater.

3. Dose to the whole body or any organ of a human for beta- and photon-emitting radionuclides in groundwater.

The calculations for the first two performance measures apply to releases from natural sources and from the repository at the same location as the RMEI.

The exposed individual would consume 2 liters (0.53 gallon) per day from the representative volume of groundwater. In the scenario, groundwater would be withdrawn annually from an aquifer that contained less than 10,000 milligrams per liter (1.3 ounces per gallon) of total dissolved solids, and centered on the highest concentration in the plume of contamination at the same location as the RMEI.

Figures F-18 and F-19 show projected total radium (radium-226 plus radium-228) and mean activity concentrations of gross alpha activity (excluding radon and uranium), respectively, in the representative

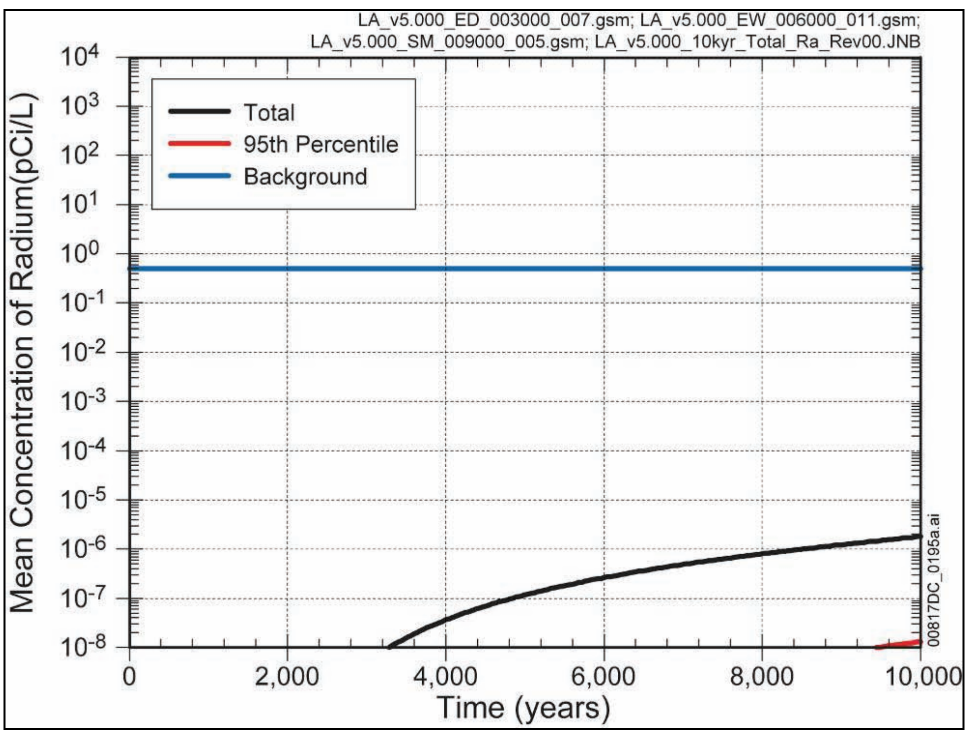

Figure F-18. Combined radium-226 and -228 activity concentrations, excluding natural background, for likely features, events, and processes using nominal, early failure, and seismic ground motion damage processes.

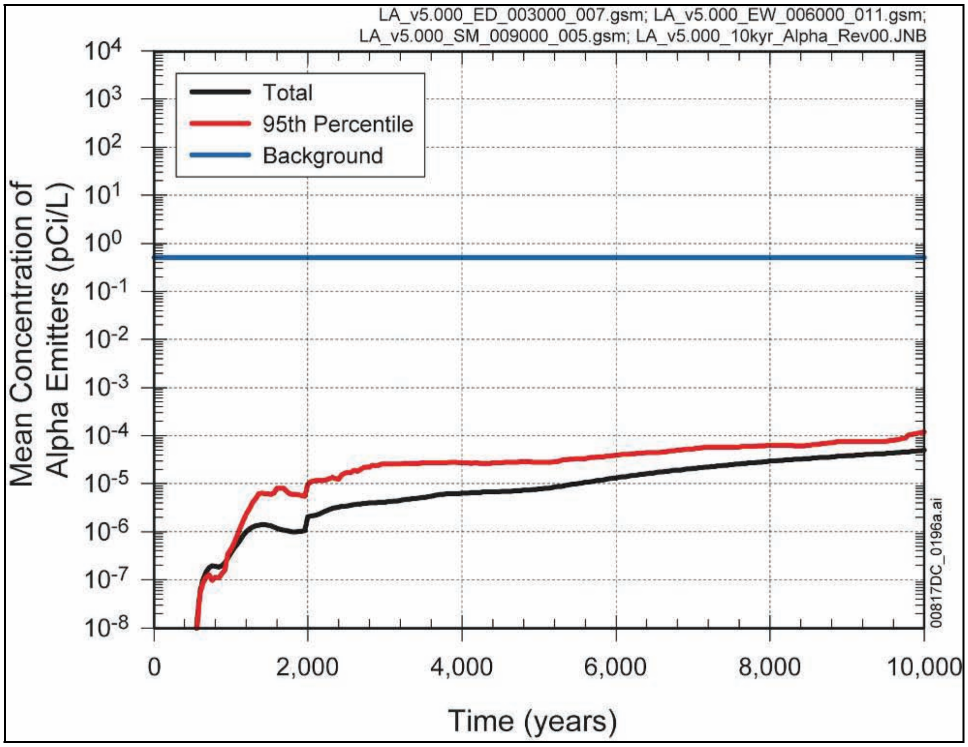

Figure F-19. Combined activity concentrations of all alpha emitters (including radium-226 but without radon and uranium isotopes), excluding natural background, for likely features, events, and processes using nominal, early failure, and seismic ground motion damage processes.

volume of groundwater for the Proposed Action inventory. The projected mean concentration for total radium in 10,000 years after closure is less than 2×10^{-6} picocurie per liter. The projected mean concentration of gross alpha activity during that period is less than 5×10^{-5} picocurie per liter. Naturally occurring background radionuclide concentrations are illustrated in the figures but were not included in the calculations because the calculated values would be negligible in comparison to background concentrations (about 0.5 picocurie per liter) up to 10,000 years.

Figure F-20 shows calculated whole-body and organ annual doses due to beta- and photon-emitting radionuclides in the groundwater. DOE calculated these annual doses from the concentrations of all of the beta- and photon-emitting radionuclides in the TSPA-SEIS model. The concentrations of these radionuclides were evaluated in terms of total annual release from the repository dissolved in the representative water volume. Figure F-20 shows the mean annual drinking water doses for thyroid and whole body (without their organ-dose weighting factors). The organ with the highest annual dose would be the thyroid, and the projected mean annual drinking water dose to the thyroid is less than 0.2 millirem. The whole-body dose in the figure accounts for the effect on all organs and includes the organ dose weighting factors. The projected mean annual drinking water dose to the whole body in this case is about 0.04 millirem.

Table F-4 summarizes the standards and projected impacts in relation to the groundwater protection standard. In addition, it lists the combined whole-body or organ doses over 10,000 years for the total of all beta- and photon-emitting radionuclides.

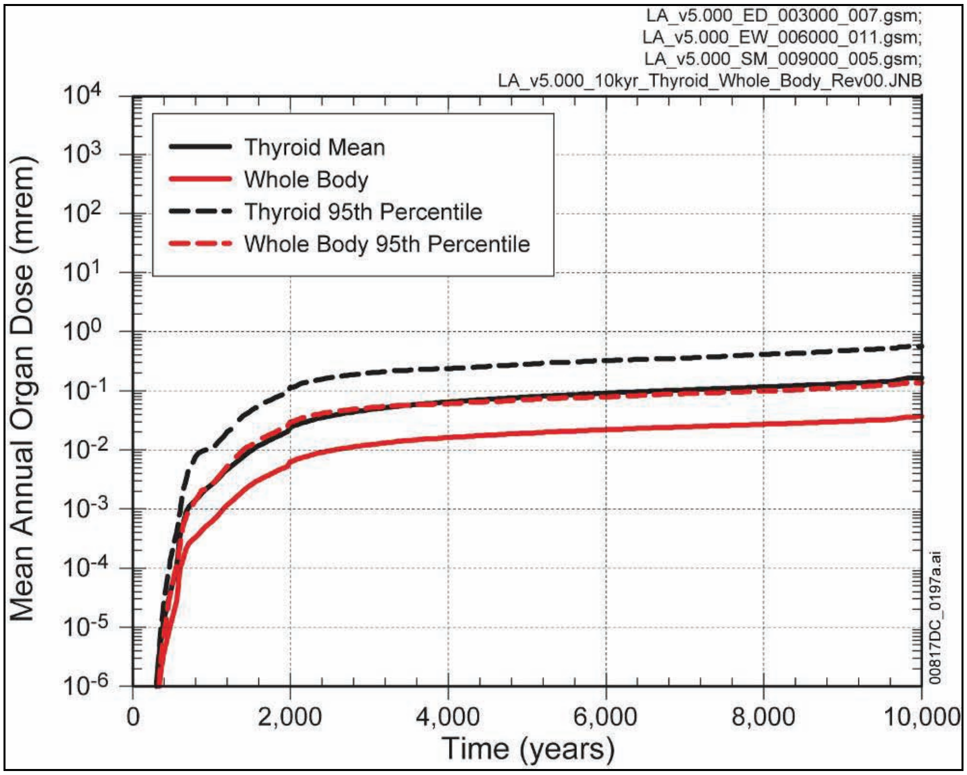

Figure F-20. Mean annual drinking water dose from combined beta and photon emitters for likely features, events, and processes using the nominal, early failure, and seismic ground motion damage processes.

Table F-4. Comparison of estimated postclosure impacts at the RMEI location to groundwater protection standards during 10,000 years following repository closure—for likely features, events, and processes using the nominal, early failure, and seismic ground motion damage processes.

Radionuclide or type of radiation	EPA limit	Mean	95th-percentile
Combined radium-226 and -228 (picocuries per liter)	5	1.8×10^{-6}	1.3×10^{-8}
Gross alpha activity (including radium-226 but excluding radon and uranium) (picocuries per liter)	15	4.9×10^{-5}	1.2×10^{-4}
Combined beta-and photon-emitting radionuclides (millirem per year to the whole body or any organ), based on drinking 2 liters of water per day from the representative volume	4	0.2	0.6

Source: DIRS 182846-SNL 2007, all.
Note: Conversion factors are on the inside back cover of this Repository SEIS.
RMEI = Reasonably maximally exposed individual.

F.5 Waterborne Chemically Toxic Material Impacts

DOE did not use the TSPA-SEIS model to estimate the postclosure impacts from waterborne chemically toxic materials because the model is unsuitable for this purpose. Rather, it used a bounding analysis to estimate impacts. Waterborne chemically toxic materials are products of the degradation of repository and waste package construction materials. The following sections describe the development of a final list of materials of concern from the larger list in Section F.3 and the bounding analysis DOE performed on those materials of concern.

F.5.1 SCREENING ANALYSIS

The Yucca Mountain FEIS contains a discussion of the screening analysis, which this Repository SEIS incorporates by reference (DIRS 155970-DOE 2002, pp. I-52 to I-59). DOE eliminated copper and manganese from further consideration due to bounding concentration limits from low solubility.

Since the Yucca Mountain FEIS was completed, there has been additional research conducted into the corrosion behavior of many of the metals within the repository. One aspect of this research was a shift in the conclusions concerning speciation of chromium evolving from corrosion of materials such as Alloy-22 and various grades of stainless steel. At the time of the FEIS it was conservatively assumed that corrosion of these materials would result in a dominant valence +6 form of chromium [chromium(VI)]. More recent work has revealed that the chemical conditions within the repository will result in corrosion products dominated by chromium valence +3 [chromium(III)] (DIRS 169860-BSC 2004, Section 6.8.1.2).

Chromium VI is a highly soluble form of chromium while chromium III is a nearly insoluble form. This means that as chromium is dissolved from the corroding materials, it is rapidly precipitated as a mineral (Cr_2O_3, various hydroxides, or other species depending on pH and other chemicals present). The solubility of chromium III is dependent on pH but is generally very low. The repository drift environment will have a pH ranging from about 6 to 12 (DIRS 169860-BSC 2004, Figure 6.13-26). Geochemical simulations in the repository drift environment showed chromium III solubility would be less than 1×10^{-3} milligram/liter for the pH 6 – 12 (DIRS 169860-BSC 2004, Figure 6.8-4). Another study in the general literature showed measurements of solubility in a high pH environment at temperatures up to 288°C on the order of 5×10^{-6} milligram/liter (DIRS 181408-Ziemniak et al. 1998, all). Another study with solutions ranging from pH 6-12, found the solubility to be 5×10^{-3} milligram/liter (DIRS 182718-Rai and Rao 2005, Figure 4). All of these values fall well below the Maximum Concentration Limit Goal of 0.1 milligram/liter set by EPA (40CFR 141.51). As water leaves the repository and is captured in the representative volume, it will have concentrations much less than the source values at the repository due to the dilution in 3,000 acre-feet per year representative volume. Thus chromium can be expected to have a concentration in the representative volume of much less than the Maximum Concentration Limit Goal. Therefore, chromium is excluded from further analysis.

F.5.2 BOUNDING CONSEQUENCE ANALYSIS FOR CHEMICALLY TOXIC MATERIALS

DOE evaluated waterborne chemically toxic materials (molybdenum, nickel, and vanadium) because the screening analysis (Section F.6.1) indicated that the repository could release such materials into groundwater in substantial quantities and that they could represent a potential human-health impact. This section contains a bounding calculation for concentrations in the biosphere of these elements and shows that the impacts are estimated to be low enough to preclude a need for more detailed modeling.

F.5.2.1 Assumptions

DOE applied the following assumptions to the bounding impact analysis for waterborne chemically toxic materials:

1. The general corrosion rate of Alloy-22 is for fresh water at 37.8°F (100°C) under expected bounding repository conditions; this does not include local corrosion because that mechanism would not release a significant amount of material.

2. The general corrosion rate of 316 stainless steel is for fresh water at 122° to 212°F (50° to 100°C) under expected bounding repository conditions; this does not include local corrosion because that mechanism would not release a significant amount of material.

3. Drip shields do not effectively delay the onset of general corrosion of Alloy-22 in the outer barrier layer of waste packages or the emplacement pallets; the basis for this is conservatism.

4. Consistent with Assumptions 1, 2, and 3 above, exposed Alloy-22 and Stainless Steel Type 316NG in the drip shield rail, external surface of the waste packages, and emplacement pallets would be subject to corrosion at the same time.

5. Consistent with Assumptions 1, 2, and 3 above, all waste packages would be subject to general corrosion at the same time, and would not experience variability in the time corrosion began.

6. A migration pathway for mobilized waterborne chemically toxic materials through the engineered barrier system to the vadose zone would exist at all times when general corrosion was in progress.

7. This bounding impact estimate neglected time delays, mitigation effects by sorption in rocks, and other beneficial effects of transport in the geosphere; the mass of mobilized waterborne chemically toxic materials would be instantly available at the biosphere exposure locations.

8. The concentration in groundwater was estimated by diluting the released mass of waterborne chemically toxic materials in the representative volume [3.7 million cubic meters (3,000 acre-feet) of water per year].

9. Release rates of molybdenum, nickel, and vanadium would be equivalent to the corrosion loss of Stainless Steel Type 316NG or Alloy-22 multiplied by the fraction of each element in the alloys.

F.5.2.2 Surface Area Exposed to General Corrosion

Corrosion of materials that contained molybdenum, nickel, and vanadium would occur over all exposed surface areas. This section describes the calculation of the total exposed surface area of Alloy-22 surfaces (drip shield rails, outer layer of waste packages, and portions of the emplacement pallets) and Stainless Steel Type 316NG surfaces (portions of the emplacement pallets and ground control structures).

Tables F-5 and F-6 summarize the calculation of the total exposed surface areas for Alloy-22 in the waste packages and drip shields, respectively, under the Proposed Action. Table F-7 summarizes the calculation of total exposed surface area for the Alloy-22 components of the emplacement pallets. The sum of exposed total surface areas for waste packages, drip shield rails, and emplacement pallet

Table F-5. Total exposed surface area of the Alloy-22 outer layer of all waste packages.

Waste package type	Number[a]	Outer diameter[b] (millimeters)	Length[b] (millimeters)	Surface area (square millimeters)	Total surface area (square meters)
21 PWR/44 BWR TAD	7,365	1,963	5,850	36,076,636	265,704
5 DHLW Short/1 DSNF Short	1,147	2,126	3,697	24,692,359	28,322
5 DHLW Long/1 DOE SNF Long	1,406	2,126	5,304	35,425,554	49,808
2 MCO/2DHLW	149	1,831	5,279	30,366,160	4,525
5 DHLW Long/1 DOE SNF Short	31	2,126	5,304	35,425,554	1,098
HLW Long Only	679	2,126	5,304	35,425,554	24,054
Naval Short	90	1,963	5,215	32,160,625	2,894
Naval Long	310	1,963	5,850	36,076,636	11,184
Totals	11,177				387,589

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Number of waste packages from DIRS 176937-DOE 2006, Table 2-11.
b. Waste package data from DIRS 179710-BSC 2007, all; DIRS 180192-BSC 2007, all; DIRS 179870-BSC 2007, all; DIRS 175303-BSC 2007, all; DIRS 180180-BSC 2007, all; DIRS 180187-BSC 2007, all; DIRS 182714-Morton 2007, all.

BWR = Boiling-water reactor.
DHLW = DOE high-level radioactive waste.
DSNF = DOE spent nuclear fuel.
MCO = Multicanister overpack.
PWR = Pressurized-water reactor.

Table F-6. Total exposed surface area of the Alloy-22 rails for all drip shields under the Proposed Action inventory.

Drip shield component	Number of pieces	Total waste package emplacement length[a,b] (meters)	Width[c] (millimeters)	Thickness[c] (millimeters)	Total surface area for repository[f] (square meters)
Rail	2	60,999	115	10	16,470

Note: Conversion factors are on the inside back cover of this Repository SEIS.
a. Sum of the waste package lengths plus a 0.1-meter (4-inch) spacing between packages.
b. Waste package data from DIRS 179710-BSC 2007, all; DIRS 180192-BSC 2007, all; DIRS 179870-BSC 2007, all; DIRS 175303-BSC 2007, all; DIRS 180180-BSC 2007, all; DIRS 180187-BSC 2007, all.
c. Rail dimensions from DIRS 150558-CRWMS M&O 2000, all.
d. Surface area calculated for the wetted surfaces (top and sides) of the rail.

components fabricated from Alloy-22 (from Tables F-5 to F-7) would be 576,362 square meters (6.2 million square feet). This would be the area of Alloy-22 subject to general corrosion under the assumptions for this bounding impact estimate.

Table F-8 summarizes the calculation of the total exposed surface areas for Stainless Steel Type 316NG DOE would use in the emplacement pallets for the Proposed Action.

The stainless-steel ground support components for the emplacement drifts in the proposed repository would consist of perforated steel sheets, friction-type rock bolts, and bearing plates. The estimated exposed surface area of the stainless-steel ground support components is 2,317, 902 square meters (approximately 25 million square feet) (DIRS 182709-Duan 2007, all). Note that the figures given in the reference accounted for overlap of sheets and did not account for material facing the rock. The figures were increased for this analysis to include all surfaces with no reduction for overlap.

The total exposed stainless steel would be the sum of the pallets (Table F-8) plus the ground support, which would be about 2.5 million square meters (27.5 million square feet).

Table F-7. Total exposed surface area of the Alloy-22 components for all emplacement pallets under the Proposed Action.[a]

Emplacement pallet component	Number of pieces	Length (millimeters)	Width (millimeters)	Number of sides	Total surface area per pallet (square meters)	Number of pallets	Total surface area repository (square meters)
Plate 1	2	1,845	552.4	1	2.038[b]		
Plate 2	2	922.5	614	2	2.266[c]		
Plate 3	2				2.219[d]		
Plate 4	4	552	462	2	2.040[e]		
Plate 5	4	552	80	2	0.353[f]		
Plate 6	4	1,266.7	603.2	2	6.113[g]		
Plate 7	4	152.4	79.9	2	0.049[h]		
Plate 8	4	152.4	552.4	1	0.337[i]		
Totals					15.415	11,177	172,293

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Emplacement pallet details from DIRS 150558-CRWMS M&O 2000, sketches SK-0189 Rev 0 and SK-0144 Rev 1.
b. Calculated for one wetted rectangular side.
c. Calculated for both wetted rectangular sides.
d. Surface area equal to that of Plate 2 less area covered by 5.1-centimeter (2.0-inch) tube cross-sections.
e. Calculated assuming rectangular area covered by tubes is not wetted; while the inside and outside are covered by tubes, the width dimension is correct for each side.
f. Calculated assuming rectangular wetted area.
g. Calculated assuming wetted area includes exposed edge thicknesses that are added to the length and width.
h. Calculated based on triangular area.
i. Calculated assuming one wetted side only (because it is covered by the tube).

Table F-8. Total exposed surface area of the Stainless Steel Type 316NG components for all emplacement pallets under the Proposed Action inventory.

Emplacement pallet tubes	Number of pieces[a]	Length[a] (millimeters)	Width[a] (millimeters)	Number of sides[a]	Total surface area per average waste package[b] (square meters)	Number of waste packages[c,d]	Total surface area repository (square meters)
Long pallets	4	4,147	609.6	2	20.224[e]	10,030	202,846
Short pallets	4	2,500	609.6	2	12.192[f]	1,147	13,984
Totals						11,177	216,830

Note: Conversion factors are on the inside back cover of this Repository SEIS.

a. Emplacement pallet details from DIRS 150558-CRWMS M&O 2000, sketches SK-0189 Rev 0 and SK-0144 Rev 1.
b. Calculated for area of all wetted rectangular sides.
c. Waste package data from DIRS 180187-BSC 2007, all.
d. Only waste packages of type 5 DHLW Short/1 DSNF Short use the short pallets.

F.5.2.3 General Corrosion Rates

DOE used the general corrosion rates of the alloys to calculate the dissolution rates of individual metals. These general corrosion rates are the same as those that DOE used in the TSPA-SEIS model.

F.5.2.3.1 *Alloy-22 Corrosion Rate*

This analysis used the mean value of the distribution of Alloy-22 corrosion rates. The mean was used as representative of a variety of locations and conditions of the waste packages.

The general corrosion rate of Alloy-22 in the TSPA-SEIS model is (DIRS 181031–SNL 2007, p. 2-1):

$$\ln(R_T) = \ln(R_0) + C_1\left(\frac{1}{T_0} - \frac{1}{T}\right) \quad \text{(Equation F-4)}$$

where

- R_T = General corrosion rate (nanometers per year) at temperature T, (kelvin)
- R_0 = General corrosion rate at 333.15 kelvin
- T_0 = 333.15 kelvin
- C_1 = temperature coefficient (in kelvin).

The parameter C_1 is a truncated normal distribution (plus or minus 2 standard deviations) with a mean of 4,905 kelvin and standard deviation of 1,413 kelvin (DIRS 181031-SNL 2007, Table 1-1). DOE used the mean value for this analysis.

R_0 is a two-parameter Weibull distribution. The scale parameter b for the distribution is 8.134 for 90-percent realizations (medium uncertainty) and the shape parameter c for the distribution is 1.476 for medium uncertainty (DIRS 181031- SNL 2007, Table 1-1).

The mean of the Weibull distribution is given by ReliaSoft Corporation (DIRS 182720-ReliaSoft 2007, all). Then:

$$R_0 = b\ \Gamma\left(1 + \frac{1}{c}\right) \quad \text{(Equation F-5)}$$

where Γ is a gamma function. Then:

$$R_0 = 8.134\ \Gamma\left(1 + \frac{1}{1.476}\right) = 8.134\ \Gamma(1.677) \quad \text{(Equation F-6)}$$

$\Gamma(1.677) = 0.905$ so that $R_0 = 7.36$ nanometers per year.

Let T = 373.15 kelvin (100°C); then, substituting into Equation F-4:

$$\ln(R_T) = \ln(7.36) + 4905\left(\frac{1}{333.15} - \frac{1}{373.15}\right) = 3.5756 \quad \text{(Equation F-7)}$$

Then R_T = 35.7 nanometers (0.0000014 inch) per year. For the bounding calculations DOE used this rate for Alloy-22 general corrosion to estimate the release of the component metals.

F.5.2.3.2 *Corrosion Rate of Stainless Steel*

DOE used the mean stainless-steel corrosion rates for TSPA-SEIS model (DIRS 169982-BSC 2004, Table 7-1, p. 7-1). The mean was used as representative of a variety of locations and types of materials over the entire repository. The mean corrosion rate for Stainless Steel Type 316NG in fresh water at 50°C to 100°C (122°F to 212°F) would be 0.248 micrometer (0.0000242 inch) per year.

F.5.2.4 Dissolution Rates

DOE calculated the rate of dissolution of waterborne chemically toxic materials as the product of the surface area exposed to general corrosion, the general corrosion rate, and the weight fraction of the alloy for the toxic material of interest. Alloy-22 consists of, among other elements, 14.5 percent (maximum) molybdenum, 57.2 percent nickel, and 0.35 percent vanadium (DIRS 104328-ASTM 1998, all). Stainless Steel Type 316NG is essentially the same as Stainless Steel Type 316L, which consists of, among other elements, 12 percent nickel, and 2.5 percent molybdenum with no vanadium (DIRS 102933-CRWMS M&O 1999, p. 13).

Table F-9 lists the calculation of the bounding mass dissolution rates for the Proposed Action.

Table F-9. Bounding mass dissolution rates (grams per year) from Alloy-22 and Stainless Steel Type 316NG components from general corrosion for the Proposed Action.

Alloy	Total exposed surface area in repository (square meters)	General corrosion rate (meters per year)	Alloy release volume (cubic meters per year)	Alloy density (grams per cubic meter)	Bounding mass dissolution rate (gram per year)			
					Alloy	Molybdenum	Nickel	Vanadium
Alloy-22	576,362	3.57×10^{-8}	0.014	8,690,000	182,712	26,493	104,512	640
316NG	2,533,932	2.48×10^{-7}	0.628	7,980,000	5,01,475	125,368	601,770	0
Totals						151,861	706,282	640

Note: Conversion factors are on the inside back cover of this Repository SEIS.

F.5.2.5 Summary of Bounding Impacts

DOE based the bounding maximum concentration on the release rate of the source materials and the representative volume for dilution prescribed in EPA regulation 40 CFR Part 197. Dilution of the bounding release rates in Section F.6.2.4 for molybdenum, nickel, and vanadium in the prescribed representative volume of water (3.7 million cubic meters, or exactly 3,000 acre-feet per year) for calculation of groundwater protection impacts for waterborne radioactive materials resulted in the bounding concentration in groundwater at exposure locations for these chemically toxic materials (Table F-10).

Table F-10. Bounding concentrations of waterborne chemical materials.

Material	Maximum bounding concentration(milligrams per liter)
Molybdenum	0.04
Nickel	0.19
Vanadium	0.0001

In order to put these concentrations in perspective, a comparison of the intake from the maximum bounding concentrations in Table F-10 to the oral reference dose for each of these materials is presented.

Table F-11 lists the intakes by chemical under the assumption of water consumption of 2 liters (0.53 gallon) per day by a 70-kilogram (154-pound) person and the relevant oral reference dose.

Table F-11. Intake of waterborne chemical materials of concern based on maximum bounding concentrations listed in Table F-10 compared to Oral Reference Doses (milligrams per kilogram of body mass per day).

Material	Oral reference dose	Intake[a]
Molybdenum	0.005[b]	0.001
Nickel	0.02[c]	0.005
Vanadium	0.007[d]	0.000003

a. Assumes a daily intake of 2 liters (0.53 gallon) per day by a 70-kilogram (154-pound) individual.
b. Source: DIRS 148228-EPA 1999, all.
c. Source: DIRS 148229-EPA 1999, all.
d. Source: DIRS 103705-EPA 1997, all.

Because the bounding concentrations of molybdenum, nickel, and vanadium in groundwater yield intakes well below the respective Oral Reference Doses, there was no further need to refine the calculation to account for physical processes that would further reduce concentration of these elements during transport in the geosphere.

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Appendix G

Transportation

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G. TRANSPORTATION

G.1 Introduction

This appendix to the *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) (Repository SEIS) summarizes the methods and data the U.S. Department of Energy (DOE or the Department) used to estimate the potential transportation impacts to workers and the public from shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository. This appendix summarizes, incorporates by reference, and updates the analyses in Appendix J of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F; DIRS 155970-DOE 2002, pp. J-1 to J-199) (Yucca Mountain FEIS).

Section G.1 discusses the methods and data used to estimate impacts at generator sites from loading activities. Section G.2 presents the representative transportation routes DOE would use to ship spent nuclear fuel and high-level radioactive waste from those sites to the proposed repository, Section G.3 lists the numbers of shipments from each site, and Section G.4 describes the radionuclide inventories the analysis used for estimation of impacts. Section G.5 presents the analysis and results for incident-free transportation, and Sections G.6 and G.7 describe transportation accident risks and the analysis of severe transportation accidents, respectively. Section G.8 disscusses sabotage events in relation to transportation. Section G.9 discusses general topics DOE examined for this analysis. Section G.10 presents the analysis and detailed results for transportation in Nevada, and Section G.11 provides those for transportation impacts due to transport of materials and personnel during construction and operation of the repository. Section G.12 contains figures of the representative transporation routes for each state through which shipments would pass, and lists the impacts of those shipments in those states.

G.2 Impacts at Generator Sites

This section describes the methods and data used to estimate the impacts from loading activities at generator sites. For rail shipments of commercial spent nuclear fuel from the generator sites, loading operations would include placement of the spent nuclear fuel into a transportation, aging, and disposal (TAD) canister, placement of the TAD canister into a rail transportation cask, and placement of the transportation cask on a railcar or heavy-haul truck. For truck shipments of commercial spent nuclear fuel, uncanistered spent nuclear fuel would be placed in a truck transportation cask and the truck cask would be placed on a truck trailer.

DOE would load its spent nuclear fuel into disposable canisters at three DOE sites and high-level radioactive waste into disposable canisters at four DOE sites. Loading operations would consist of placement of the canisters into a rail transportation cask and placement of the transportation cask on a railcar. A small amount of uncanistered spent nuclear fuel would be loaded into truck casks at the DOE sites.

G.2.1 IMPACTS OF SHIPPING CANISTERS AND CAMPAIGN KITS TO GENERATOR SITES

DOE would operate the proposed repository using a primarily canistered approach in which most commercial spent nuclear fuel would be packaged at the generator sites into TAD canisters. This would require shipment of TAD canisters to the commercial generator sites. These shipments of empty canisters would be by truck. Before the loading of a truck or rail transportation cask, equipment used in the handling and loading of the cask, known as a campaign kit, would be shipped to the generator sites. These shipments would also be by truck.

The shipments of canisters would not be radioactive material shipments, so there would be no radiation dose to the public or to workers from them. The campaign kits could become contaminated during use, but would be decontaminated before shipping. Therefore, the radiation dose and radiological risks associated with the shipping of campaign kits would be negligible. The impacts of transporting canisters and campaign kits would be from fatalities from exposure to vehicle emissions and traffic fatalities. Injuries were not estimated because they are not readily combined with radiological impacts, which were quantified in terms of latent cancer fatalities. DOE estimated these impacts based on a 6,000-kilometer (3,700-mile) round-trip shipping distance for the canisters and the campaign kits and a population density of 220 people per square kilometer (570 people per square mile). The Department used data from the 2000 Census extrapolated to 2067 to estimate the population density along the representative truck routes (see Section G.2).

Table G-1 summarizes the data DOE used to estimate the impacts of these shipments.

Table G-1. Data used to estimate impacts from shipping canisters and campaign kits.

Quantity	Value	Reference
Number of canisters shipped	6,499[a]	DIRS 181377-BSC 2007, Section 7
Number of campaign kits shipped	4,942	DIRS 181377-BSC 2007, Section 7
Vehicle emission fatality rate	1.5×10^{-11} fatalities/km per person/km^2	DIRS 157144-Jason Technologies 2001, p. 98
Traffic fatality rate	1.71×10^{-8} fatalities/km	DIRS 182082-FMCSA 2007, Table 13

Notes: Vehicle emission fatality rate and traffic fatality rate are for trucks. Conversion factors are on the inside back cover of this Repository SEIS.

a. About an additional 1,000 empty TAD canisters would be shipped directly to the repository to package commercial spent nuclear fuel that could not be shipped from the generator sites using rail casks.

km = kilometer.

G.2.2 RADIOLOGICAL IMPACTS TO WORKERS FROM LOADING

At commercial generator sites, impacts to involved workers would result from loading spent nuclear fuel into canisters, loading canisters into rail transportation casks, and, at some sites, loading spent nuclear fuel into truck casks. For DOE spent nuclear fuel and high-level radioactive waste, impacts would result from loading canisters into rail transportation casks and a small amount of uncanistered spent nuclear fuel into truck casks. Noninvolved workers would not be in proximity to the canisters or casks and would not be exposed during loading. Therefore, DOE did not estimate radiological impacts for these noninvolved workers. Table G-2 summarizes the data DOE used to estimate the radiological impacts from these activities.

A TAD canister is similar to a dry storage canister in appearance, capacity, and the operational procedures that would be in use for loading. Therefore, for the loading of spent nuclear fuel into TAD canisters at commercial generator sites, DOE based radiation doses on utility data compiled by the U.S. Nuclear Regulatory Commission (NRC) for loading 87 dry storage canisters at four commercial sites (DIRS 181757-NRC 2002, Attachment 3; DIRS 181758-Spitzberg 2004, Attachment 2; DIRS 181759-Spitzberg

Table G-2. Data used to estimate radiation doses to workers for loading.

Operation	Radiation dose	Number of canisters or casks for operation	Reference
Rail cask			
Load commercial spent nuclear fuel into canister	0.400 person-rem per canister	6,499 canisters[a]	Average of utility data in DIRS 181757-NRC 2002, Attachment 3; DIRS 181758-Spitzberg 2004, Attachment 2; DIRS 181759-Spitzberg 2005, Attachment 2; DIRS 181760-Spitzberg 2005, Attachment 2
Transfer canister from storage, load into rail cask, load rail cask onto railcar	0.663 person-rem per cask	9,495 casks[b]	Steps 12 and 13 in DIRS 104794-CRWMS M&O 1994, p. A-28
Truck cask			
Load uncanistered spent nuclear fuel into truck cask, load truck cask onto truck trailer	0.432 person-rem per cask	2,650 casks[c]	Steps 1, 2, 3a, 4a, and 5a in DIRS 104794-CRWMS M&O 1994, pp. A-9 to A-11

a. Includes only TAD canisters (DIRS 181377-BSC 2007, Section 7).
b. Includes commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste (DIRS 181377-BSC 2007, Section 7).
c. DIRS 181377-BSC 2007, Section 7.
DOE = U.S. Department of Energy.
TAD = Transportation, aging, and disposal (canister).

2005, Attachment 2; DIRS 181760-Spitzberg 2005, Attachment 2). Using the utility data, DOE estimated the average radiation dose for loading spent nuclear fuel into canisters to be 0.400 person-rem per canister. For comparison, the estimated radiation dose for these same activities would be 1.992 person-rem (DIRS 104794-CRWMS M&O 1994, p. A-24).

DOE used data from *Health and Safety Impacts Analysis for the Multi-Purpose Canister System and Alternatives* (DIRS 104794-CRWMS M&O 1994, pp. A-9 and A-24) to estimate radiation doses for the loading of (1) canisters containing spent nuclear fuel into rail casks and uncanistered spent nuclear fuel into truck casks, (2) canisters containing high-level radioactive waste and canisters containing DOE spent nuclear fuel into rail casks, and (3) rail casks onto railcars and truck casks onto truck trailers. For loading uncanistered spent nuclear fuel into truck casks and loading the truck casks onto trailers, the estimated radiation dose would be 0.432 person-rem per cask (DIRS 104794-CRWMS M&O 1994, p. A-9). For loading canisters into rail casks and loading the rail casks onto railcars, the estimated radiation dose would be 0.663 person-rem per cask (DIRS 104794-CRWMS M&O 1994, p. A-24).

G.2.3 INDUSTRIAL SAFETY IMPACTS TO WORKERS FROM LOADING

DOE based the analysis of industrial safety impacts on an average loading duration of 2.3 days per rail cask for pressurized-water-reactor spent nuclear fuel and 2.5 days per rail cask for boiling-water-reactor spent nuclear fuel (DIRS 155970-DOE 2002, p. J-34). For truck casks, DOE based the analysis on an average loading duration of 1.3 days per cask for pressurized-water-reactor spent nuclear fuel and 1.4 days per cask for boiling-water-reactor spent nuclear fuel (DIRS 155970-DOE 2002, p. J-34). The Department based loading durations for DOE spent nuclear fuel and high-level radioactive waste on the loading durations for pressurized-water-reactor spent nuclear fuel. It based the industrial safety impacts on a crew size of 13 (DIRS 155970-DOE 2002, p. J-34) dedicated solely to performing cask-handling work and an 8-hour working day. Based on these data, 1,347 worker-years would be spent during loading activities for involved workers. Using the assumption that the noninvolved workforce would be 25 percent of the involved workforce, DOE determined that uninvolved workers would spend 337 worker-years during loading activities for uninvolved workers (DIRS 155970-DOE 2002, p. 6-38).

DOE based incidence and fatality rates for involved workers on Bureau of Labor Statistics data for 2005 (DIRS 179131-BLS 2006, all; DIRS 179129-BLS 2007, all). Bureau of Labor Statistics data is organized into industries. DOE used data for workers in the transportation and warehousing industries to estimate impacts because they closely represent the hazards associated with loading casks. Data from DOE sources was not used because most of the generator sites were associated with private industry rather than DOE. For noninvolved workers, the Department based the rates on the professional and business services industries.

For vehicle emission fatalities, DOE based the analysis of industrial safety impacts on a vehicle emission fatality rate of 9.4×10^{-12} fatalities per kilometer per persons per square kilometer (DIRS 157144-Jason Technologies 2001, p. 99) and on a population density of 6 persons per square kilometer (16 persons per square mile), which is representative of a rural area (DIRS 101892-NRC 1977, p. E-2). For traffic fatalities, DOE based the analysis of industrial safety impacts on a fatality rate of 1.0×10^{-8} fatalities per kilometer (DIRS 182082-FMCSA 2007, Table 2) over the period from 2001 through 2005. DOE also based the analysis on workers driving 37 kilometers (23 miles) round trip for 251 days per year. Table G-3 summarizes the data DOE used to estimate the industrial safety impacts from loading activities.

Table G-3. Data used to estimate industrial safety impacts to workers for loading.

Quantity	Value	Reference
Involved workers		
Worker-years	1,347[a]	Calculated
Total recordable cases rate	0.082 per worker-year	DIRS 179131-BLS 2006, all; for warehousing and storage industries
Lost workday cases rate	0.054 per worker-year	DIRS 179131-BLS 2006, all; for warehousing and storage industries
Fatality rate	1.76×10^{-4} per worker-year	DIRS 179129-BLS 2007, all; for transportation and warehousing industries
Noninvolved workers		
Worker-years	337	Calculated
Total recordable cases rate	0.024 per worker-year	DIRS 179131-BLS 2006, all; for professional and business services, management of companies and enterprises
Lost workday cases rate	0.012 per worker-year	DIRS 179131-BLS 2006, all; for professional and business services, management of companies and enterprises
Fatality rate	3.5×10^{-5} per worker-year	DIRS 179129-BLS 2007, all; for professional and business services
Vehicle emission fatality rate	9.4×10^{-12} fatalities/km per person/km^2	DIRS 157144-Jason Technologies 2001, p. 99
Traffic fatality rate	1.0×10^{-8} fatalities per km	DIRS 182082-FMCSA 2007, Table 2

Notes: Vehicle emission fatality rate and traffic fatality rate are for automobiles. Conversion factors are on the inside back cover of this Repository SEIS.

a. Based on loading 6,736 pressurized-water-reactor spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste rail casks, 1,940 pressurized-water-reactor truck casks, 2,759 boiling-water-reactor rail casks, and 710 boiling-water reactor truck casks.

km = kilometer.

G.3 Transportation Routes

At this time, before receipt of a construction authorization for the proposed repository and years before a possible first shipment, the specific rail and highway routes shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain will use have not been identified. Consequently, the analysis of impacts presented in this supplemental environmental impact statement is based on routes that could be used and that DOE believes are representative of those that will be used. Therefore, the highway and rail routes that DOE used for analysis in this Repository SEIS are called representative routes.

DOE used the TRAGIS computer program (DIRS 181276-Johnson and Michelhaugh 2003, all) to identify the representative rail and truck routes used in the analysis. TRAGIS is a web-based geographic information system transportation routing computer code. The TRAGIS rail network is developed from a 1-to-100,000-scale rail network derived from the United States Geological Survey digital line graphs. This network currently represents more than 240,000 kilometers (150,000 miles) of rail lines in the continental United States and has over 28,000 segments (links) and over 4,000 nodes. All rail lines with the exception of industrial spurs are included. The rail network includes nodes for nuclear reactor sites, DOE sites, and military bases that have rail access. The rail network has been extensively modified and is revised on a regular schedule to reflect rail line abandonment, company mergers, short line spin-offs, and new rail construction.

To calculate rail routes, the TRAGIS computer program uses rules that are designed to simulate routing practices that have been historically used by railroad companies in moving regular freight and dedicated trains in the United States. The basic rule used to calculate rail routes causes the program to attempt to identify the shortest route from an origin to a destination. Another rule used in the program biases the lengths of route segments that have the highest density of rail traffic to make these segments appear, for purposes of calculation, to be shorter. The effect of the bias is to prioritize selection of routes that use railroad main lines, which have the highest traffic density. As a general rule routing along the high traffic lines replicates railroad operational practices. A third rule constrains the program to select routes used by an individual railroad company to lines the company owns or has permission to operate over. This rule ensures that the number of interchanges between railroads that the TRAGIS computer program calculates for a route is correct. The number of interchanges between railroads is a significant consideration when determining a realistic and representative route.

Another rule used in the TRAGIS computer program to calculate a rail route determines the sequence of different railroad companies whose rail lines would be linked to form the route. Because a delay and additional operations are involved in transferring a shipment (interchanging) from one railroad to another, in order to provide efficient service, railroads typically route shipments to minimize the number of interchanges that occur. Reducing the number of interchanges also tends to reduce the time a shipment is in transit. This practice is simulated in the TRAGIS computer program by imposing a penalty for each interchange that is identified for a route. The interchange penalties cause the TRAGIS computer program to increase the calculated length of routes when more than one railroad company's lines are linked. As a consequence, the algorithm used in the TRAGIS computer program to identify routes that have the least apparent length gives advantage to routes that also have the fewest interchanges between railroads and the fewest involved railroad companies.

Last, a rule in the TRAGIS computer program is designed to simulate the commercial behavior of railroad companies to maximize their portion of revenues from shipments. The effect of this behavior is that routing is often affected by originating railroads, who control the selection of routes on their lines to realize the as much of a shipment's revenue as possible. The result is that originating railroads transport shipments as far as possible (in the direction of the destination) on their systems before interchanging the shipments with other railroads. This behavior is simulated in the TRAGIS computer program by imposing a bias on the length of the originating railroad's lines to give the railroad an advantage when calculating a route. In evaluating the length of the route, the model treats 1 mile of travel on the originating railroad as being "less" than 1 mile on other railroads.

The TRAGIS highway network is developed from a 1-to-100,000-scale road network derived from United States Geological Survey digital line graphs and Bureau of the Census TIGER data. The network represents slightly more than 378,000 kilometers (235,000 miles) of roadways and includes all Interstate highways, most U.S. highways except those that closely parallel Interstate highways, major state highways, and other local roads that connect to various specific sites of interest. The network currently includes over 22,000 highway segments (links) and over 16,000 intersections (nodes). The network includes nuclear reactor sites, DOE sites, and commercial and military airports.

TRAGIS provides a variety of routing rules that can be used to calculate highway routes. The default rules yield highway routes that commercial motor carriers of freight would be expected to use. In addition, TRAGIS can be used to: (1) determine routes that meet the U.S. Department of Transportation regulations for shipments of highway route-controlled quantities of radioactive material; (2) identify the shortest route between an origin and destination; or (3) identify the route that could be expected to result in the least total time in transit.

The population data in TRAGIS are derived from the LandScan USA 15-arc second (approximately 360-by-460-meter) grid cell population database. This national database represents the nighttime population distribution and is developed from a combination of data sources including 2000 Bureau of the Census block group population, roads from the Bureau of the Census TIGER data, slope from the National Imagery and Mapping Agency's Digital Terrain Elevation Data, and land cover from the United States Geological Survey National Land Cover Database. The data are modeled to best approximate the actual location of the resident population. Because of the proximity of the repository to Las Vegas, the resident population in Las Vegas was modified to include casino guests and casino workers, based on data from the Nevada Agency for Nuclear Projects (DIRS 158452-Nevada Agency for Nuclear Projects 2002, Table 3.8.12).

The routes used in the analysis that are also representative of routes that could be used for shipments to the repository are illustrated in Figures G-1 and G-2. DOE determined rail routes in two steps. In the first step, representative routes were determined from the generator sites to either Caliente or Hazen, Nevada. In the second step, the rail alternative segments that comprise the rail alignment with the highest population in the Caliente or Mina rail alignment were used to determine the representative route from Caliente or Hazen to the repository. Tables G-4 and G-5 list the distances from the generator sites to Caliente and Hazen. Table G-6 lists the distances from Caliente and Hazen to the repository.

Some generator sites do not have direct rail access. For these sites, heavy-haul trucks would have to be used to move the rail cask containing spent nuclear fuel to a nearby railhead. Barges could also be used; Section G.10.10 discusses barge shipments. Table G-7 lists the distances from these generator sites to the nearby railheads.

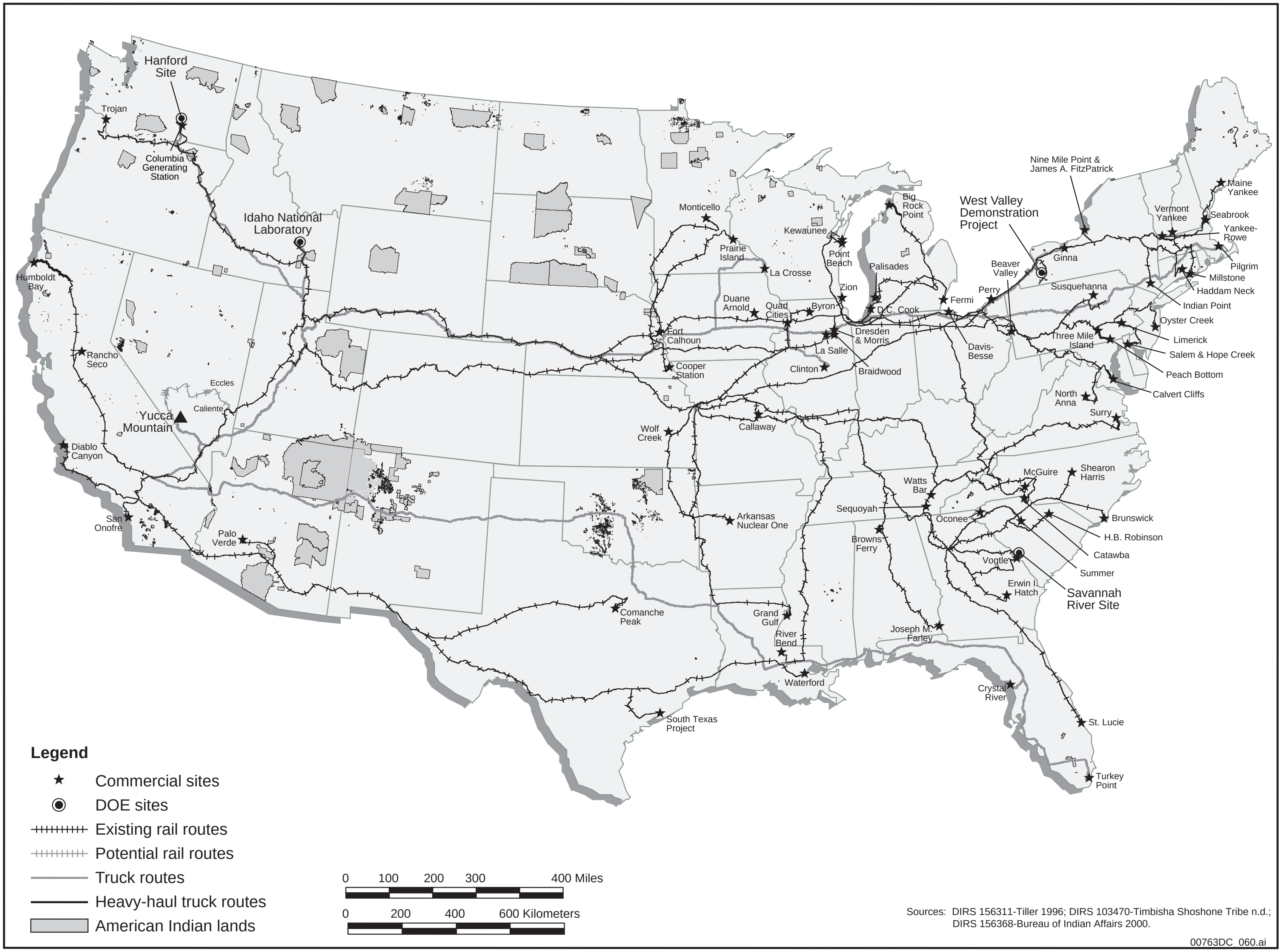

Figure G-1. Representative rail and truck transportation routes if DOE selected the Caliente rail corridor in Nevada.

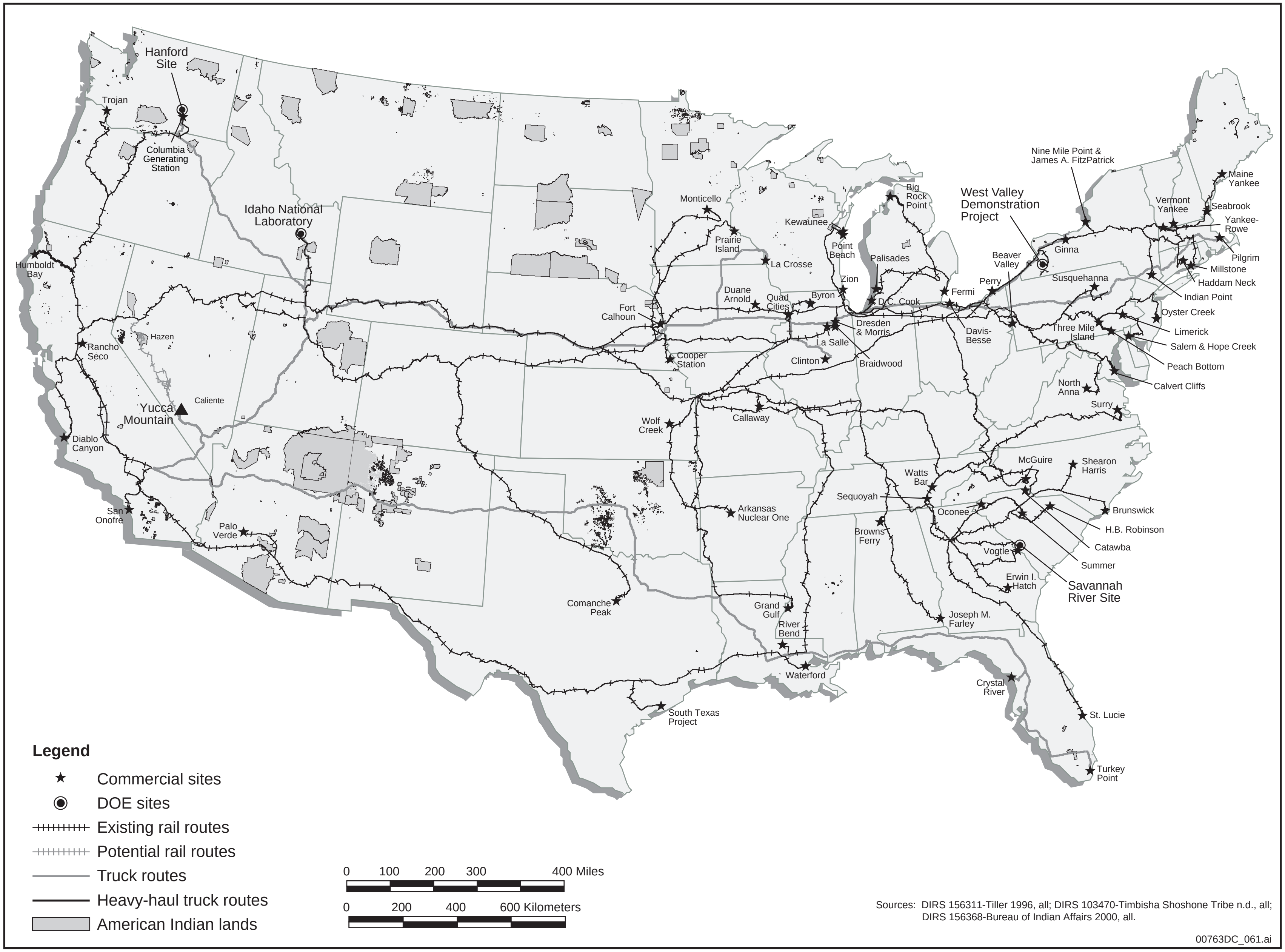

Figure G-2. Representative rail and truck transportation routes if DOE selected the Mina rail corridor.

Table G-4. Distances for representative rail routes from generator sites to Caliente, Nevada.

Origin	Origin state	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
Browns Ferry	AL	Rail	2,947.0	490.2	97.9
Farley	AL	Rail	3,331.8	643.9	109.6
Arkansas	AR	Rail	2,668.0	305.9	51.0
Palo Verde	AZ	Rail	1,216.5	197.8	63.7
Diablo Canyon	CA	Rail	781.9	166.2	131.0
Humboldt Bay	CA	Rail	1,020.2	289.4	110.1
Rancho Seco	CA	Rail	853.7	213.0	82.4
San Onofre	CA	Rail	584.1	107.1	77.1
Haddam Neck	CT	Rail	3,369.2	905.6	216.2
Millstone	CT	Rail	3,417.4	942.7	218.3
St. Lucie	FL	Rail	3,642.7	940.1	166.0
Hatch	GA	Rail	3,459.9	724.0	105.4
Vogtle	GA	Rail	3,504.7	723.5	104.5
Arnold	IA	Rail	2,240.8	288.1	46.6
Idaho National Laboratory	ID	Rail	796.1	93.4	25.7
Braidwood	IL	Rail	2,657.4	402.6	96.8
Byron	IL	Rail	2,428.5	321.3	47.4
Dresden	IL	Rail	2,479.0	367.5	62.4
LaSalle	IL	Rail	2,525.7	275.8	40.4
Morris	IL	Rail	2,478.9	367.4	62.4
Quad Cities	IL	Rail	2,456.3	283.7	42.0
Zion	IL	Rail	2,467.3	387.7	86.3
Wolf Creek	KS	Rail	2,242.7	218.5	46.9
River Bend	LA	Rail	3,288.1	584.7	106.6
Waterford	LA	Rail	3,060.6	505.1	122.6
Yankee Rowe	MA	Rail	3,284.5	797.3	190.8
Calvert Cliffs	MD	Rail	3,267.0	709.0	223.4
Maine Yankee	ME	Rail	3,484.0	991.0	235.6
Big Rock Point	MI	Rail	2,913.0	666.9	154.7
Fermi	MI	Rail	2,742.3	542.6	158.5
Palisades	MI	Rail	2,543.4	434.2	119.6
Monticello	MN	Rail	2,477.4	331.4	51.6
Prairie Island	MN	Rail	2,373.0	325.0	48.0
Callaway	MO	Rail	2,346.5	243.6	52.2
Grand Gulf	MS	Rail	3,052.8	420.7	60.1
Brunswick	NC	Rail	3,529.1	877.4	142.6
Harris	NC	Rail	3,450.6	867.4	142.3

Table G-4. Distances for representative rail routes from generator sites to Caliente, Nevada (continued).

Origin	Origin state	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
McGuire	NC	Rail	3,450.8	730.1	155.3
Cooper	NE	Rail	2,009.6	218.4	47.6
Fort Calhoun	NE	Rail	1,923.9	179.6	38.4
Seabrook	NH	Rail	3,420.0	930.0	221.5
Hope Creek	NJ	Rail	3,131.0	911.4	315.0
Oyster Creek	NJ	Rail	3,180.8	922.9	326.0
Salem	NJ	Rail	3,131.0	911.4	315.0
FitzPatrick	NY	Rail	3,138.8	698.0	192.5
Indian Point	NY	Rail	3,360.0	792.9	204.9
Nine Mile Point	NY	Rail	3,138.5	697.4	192.5
West Valley	NY	Rail	3,028.7	628.8	167.4
Davis-Besse	OH	Rail	2,695.9	485.2	143.6
Perry	OH	Rail	3,099.3	412.9	115.2
Trojan	OR	Rail	1,763.2	246.2	72.6
Beaver Valley	PA	Rail	3,170.2	463.7	110.6
Limerick	PA	Rail	3,430.7	681.5	195.3
Peach Bottom	PA	Rail	3,416.4	639.0	171.5
Susquehanna	PA	Rail	3,155.2	799.5	244.3
Three Mile Island	PA	Rail	3,398.9	633.0	171.9
Catawba	SC	Rail	3,339.1	784.0	113.3
Oconee	SC	Rail	3,275.2	734.1	112.1
Robinson	SC	Rail	3,334.6	839.8	147.6
Savannah River Site	SC	Rail	3,308.8	726.8	149.8
Summer	SC	Rail	3,385.4	839.9	119.8
Sequoyah	TN	Rail	3,086.3	526.1	85.3
Watts Bar	TN	Rail	3,057.4	502.6	84.7
Comanche Peak	TX	Rail	2,456.5	379.8	87.0
South Texas	TX	Rail	2,769.1	336.3	93.2
North Anna	VA	Rail	3,379.6	732.3	227.4
Surry	VA	Rail	3,552.7	812.2	111.0
Vermont Yankee	VT	Rail	3,390.0	881.3	201.3
Columbia	WA	Rail	1,540.6	176.9	40.0
Hanford Site	WA	Rail	1,575.1	177.0	40.0
Kewaunee	WI	Rail	2,619.9	490.8	125.8
Point Beach	WI	Rail	2,619.9	490.8	125.8

Notes: Rural areas have a population density less then 139 people per square kilometer. Suburban areas have a population density between 139 and 3,326 people per square kilometer. Urban areas have a population density greater than 3,326 people per square kilometer. Conversion factors are on the inside back cover of this Repository SEIS.

Table G-5. Distances for representative rail routes from generator sites to Hazen, Nevada.

Origin	Origin state	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
Browns Ferry	AL	Rail	3,200.6	470.3	83.2
Farley	AL	Rail	3,585.5	624.0	94.9
Arkansas	AR	Rail	2,921.6	286.0	36.3
Palo Verde	AZ	Rail	1,250.5	459.6	172.3
Diablo Canyon	CA	Rail	512.5	233.7	103.5
Humboldt Bay	CA	Rail	359.8	140.5	32.7
Rancho Seco	CA	Rail	241.3	93.8	40.0
San Onofre	CA	Rail	774.1	306.1	161.5
Haddam Neck	CT	Rail	3,622.8	885.8	201.5
Millstone	CT	Rail	3,671.0	922.8	203.6
St. Lucie	FL	Rail	3,896.3	920.3	151.3
Hatch	GA	Rail	3,713.5	704.1	90.7
Vogtle	GA	Rail	3,758.3	703.6	89.8
Arnold	IA	Rail	2,494.4	268.3	31.9
Idaho National Laboratory	ID	Rail	1,049.1	69.6	10.3
Braidwood	IL	Rail	2,911.0	382.8	82.1
Byron	IL	Rail	2,682.1	301.4	32.7
Dresden	IL	Rail	2,732.6	347.6	47.7
LaSalle	IL	Rail	2,907.3	332.5	55.3
Morris	IL	Rail	2,732.5	347.5	47.7
Quad Cities	IL	Rail	2,837.9	340.4	56.9
Zion	IL	Rail	2,720.9	367.8	71.6
Wolf Creek	KS	Rail	2,496.3	198.6	32.2
River Bend	LA	Rail	3,541.7	564.8	91.9
Waterford	LA	Rail	3,094.7	766.9	231.2
Yankee Rowe	MA	Rail	3,538.1	777.5	176.1
Calvert Cliffs	MD	Rail	3,520.6	689.1	208.7
Maine Yankee	ME	Rail	3,737.6	971.1	220.9
Big Rock Point	MI	Rail	3,166.6	647.0	139.9
Fermi	MI	Rail	2,995.9	522.8	143.7
Palisades	MI	Rail	2,797.0	414.4	104.9
Monticello	MN	Rail	2,859.0	388.1	66.5
Prairie Island	MN	Rail	2,626.6	305.2	33.2
Callaway	MO	Rail	2,600.1	223.7	37.5
Grand Gulf	MS	Rail	3,306.5	400.8	45.4
Brunswick	NC	Rail	3,782.7	857.6	127.9
Harris	NC	Rail	3,704.2	847.6	127.6

Table G-5. Distances for representative rail routes from generator sites to Hazen, Nevada (continued).

Origin	Origin state	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
McGuire	NC	Rail	3,704.4	710.2	140.6
Cooper	NE	Rail	2,263.3	198.6	32.9
Fort Calhoun	NE	Rail	2,177.5	159.8	23.7
Seabrook	NH	Rail	3,673.6	910.2	206.8
Hope Creek	NJ	Rail	3,384.6	891.5	300.3
Oyster Creek	NJ	Rail	3,434.4	903.0	311.3
Salem	NJ	Rail	,3384.6	891.5	300.3
FitzPatrick	NY	Rail	3,392.4	678.1	177.8
Indian Point	NY	Rail	3,613.6	773.0	190.2
Nine Mile Point	NY	Rail	3,392.1	677.5	177.8
West Valley	NY	Rail	3,282.3	608.9	152.7
Davis-Besse	OH	Rail	2,949.5	465.4	128.9
Perry	OH	Rail	3,352.9	393.1	100.5
Trojan	OR	Rail	1,013.2	335.4	90.9
Beaver Valley	PA	Rail	3,423.8	443.8	95.9
Limerick	PA	Rail	3,684.3	661.6	180.6
Peach Bottom	PA	Rail	3,670.0	619.2	156.8
Susquehanna	PA	Rail	3,408.9	779.6	229.6
Three Mile Island	PA	Rail	3,652.5	613.1	157.2
Catawba	SC	Rail	3,592.7	764.2	98.6
Oconee	SC	Rail	3,528.8	714.3	97.4
Robinson	SC	Rail	3,588.2	819.9	132.9
Savannah River Site	SC	Rail	3,562.4	707.0	135.1
Summer	SC	Rail	3,639.0	820.1	105.1
Sequoyah	TN	Rail	3,339.9	506.2	70.6
Watts Bar	TN	Rail	3,311.0	482.8	70.0
Comanche Peak	TX	Rail	2,731.9	340.4	65.5
South Texas	TX	Rail	2,803.2	598.0	201.9
North Anna	VA	Rail	3,633.2	712.5	212.7
Surry	VA	Rail	3,806.3	792.4	96.3
Vermont Yankee	VT	Rail	3,643.6	861.4	186.6
Columbia	WA	Rail	1,225.3	248.4	45.3
Hanford Site	WA	Rail	1,259.9	248.5	45.3
Kewaunee	WI	Rail	2,873.5	470.9	111.1
Point Beach	WI	Rail	2,873.5	470.9	111.1

Notes: Rural areas have a population density less then 139 people per square kilometer. Suburban areas have a population density between 139 and 3,326 people per square kilometer. Urban areas have a population density greater than 3,326 people per square kilometer. Conversion factors are on the inside back cover of this Repository SEIS.

Table G-6. Distances from Caliente and Hazen to the repository.

Origin	County	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
Caliente					
	Lincoln	Rail	148.75	0.35	0
	Nye	Rail	358.64	0	0
	Esmeralda	Rail	31.08	0.12	0
Hazen					
	Churchill	Rail	18.61	0	0
	Lyon	Rail	89.09	0.88	0
	Mineral	Rail	154.81	0	0
	Esmeralda	Rail	132.76	0.11	0
	Nye	Rail	149.55	0	0

Notes: Rural areas have a population density less then 139 people per square kilometer. Suburban areas have a population density between 139 and 3,326 people per square kilometer. Urban areas have a population density greater than 3,326 people per square kilometer. Conversion factors are on the inside back cover of this Repository SEIS.

Table G-7. Distances for representative heavy-haul truck routes from generator sites to nearby railroads.

Origin	Origin state	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
Browns Ferry	AL	Heavy haul[a]	19.4	8.4	0.4
Diablo Canyon	CA	Heavy haul[a]	22.3	7.0	2.6
Humboldt Bay	CA	Heavy haul	206.8	28.5	6.1
Haddam Neck	CT	Heavy haul[a]	10.2	9.6	1.0
St. Lucie	FL	Heavy haul[a]	13.0	7.5	0.6
Yankee Rowe	MA	Heavy haul	25.9	7.0	1.3
Calvert Cliffs	MD	Heavy haul[a]	25.4	31.5	0.3
Big Rock Point	MI	Heavy haul	60.5	12.0	0.8
Palisades	MI	Heavy haul[a]	15.9	13.9	0.1
Callaway	MO	Heavy haul	19.1	1.9	0.6
Grand Gulf	MS	Heavy haul[a]	32.6	2.2	0.0
Cooper	NE	Heavy haul[a]	18.0	1.8	0.2
Fort Calhoun	NE	Heavy haul	3.7	1.4	0.3
Hope Creek	NJ	Heavy haul[a]	29.3	6.5	0.2
Oyster Creek	NJ	Heavy haul[a]	6.0	17.4	5.1
Salem	NJ	Heavy haul[a]	29.0	6.1	0.2
Indian Point	NY	Heavy haul[a]	0.9	1.1	1.4
Peach Bottom	PA	Heavy haul	29.4	18.5	6.6
Oconee	SC	Heavy haul	8.2	3.3	0.0
Surry	VA	Heavy haul[a]	37.1	12.0	0.3
Kewaunee	WI	Heavy haul[a]	35.7	5.2	0.2
Point Beach	WI	Heavy haul[a]	30.8	5.0	0.2

Notes: Rural areas have a population density less then 139 people per square kilometer. Suburban areas have a population density between 139 and 3,326 people per square kilometer. Urban areas have a population density greater than 3,326 people per square kilometer. Conversion factors are on the inside back cover of this Repository SEIS.

a. Could also ship by barge.

Some generator sites do not have the ability to handle a rail cask at their facilities. Unless site capabilities are upgraded at these sites, truck casks would have to be used to ship the spent nuclear fuel. In addition, there would be a small number of commercial spent nuclear fuel truck shipments from the Hanford Site and the Idaho National Laboratory. For truck shipments, DOE determined the representative routes based on the U.S. Department of Transportation rules for Highway Route-Controlled Quantity shipments in 49 CFR 397.101. Figures G-1 and G-2 show the representative truck routes used in the analysis from these generator sites to the repository and Table G-8 lists the distances from these generator sites to the repository.

Table G-8. Distances for representative truck routes from generator sites to the repository.

Origin	Origin State	Mode	Rural kilometers	Suburban kilometers	Urban kilometers
Crystal River	FL	Truck	3,552.8	834.3	113.9
Turkey Point	FL	Truck	3,910.8	998.7	154.8
Idaho National Laboratory	ID	Truck	951.0	196.9	48.0
Clinton	IL	Truck	2,636.6	394.7	51.4
Pilgrim	MA	Truck	3,480.3	1086.8	120.8
Cook	MI	Truck	2,654.5	452.1	65.8
Ginna	NY	Truck	3,139.4	824.1	109.6
Hanford Site	WA	Truck	1,531.1	286.6	59.9
LaCrosse	WI	Truck	2,616.0	328.5	55.7

Notes: Rural areas have a population density less then 139 people per square kilometer. Suburban areas have a population density between 139 and 3,326 people per square kilometer. Urban areas have a population density greater than 3,326 people per square kilometer. Conversion factors are on the inside back cover of this Repository SEIS.

The population density data DOE used in this Repository SEIS from TRAGIS and for the Caliente and Mina rail alignments were for 800 meters (0.5 mile) on either side of the representative rail or truck route and were based on 2000 Census data. Because the analysis considered that the repository would operate for 50 years, DOE used Bureau of the Census population estimates for 2000 through 2030 to extrapolate population densities along the routes to 2067. DOE used population estimates for 2026 through 2030 to extrapolate population densities for 2031 through 2067. In Nevada, DOE used the *Regional Economic Model, Inc. (REMI)* computer model and data from the Nevada State Demographer to extrapolate population densities. Table G-9 lists the population escalation factors. DOE estimated 2067 population within this 1,600-meter (1 mile) band by multiplying by the appropriate state population escalation factor.

G.4 Shipments

The Yucca Mountain FEIS (DIRS 155970-DOE 2002, Tables J-5, J-6, and J-7) analyzed the shipment of 9,646 rail casks and 1,079 truck casks of spent nuclear fuel and high-level radioactive waste to the repository. Since the completion of the Yucca Mountain FEIS in 2002, DOE has updated the number of rail and truck casks to be shipped to the repository through additional data collection and analysis. In addition, the Department has developed updated estimates of shipments that incorporate the use of TAD canisters and updated cask handling assumptions at each reactor site. Table G-10 summarizes the number of rail and truck casks that would be shipped to the repository. From these estimates, there would be 9,495 rail casks and 2,650 truck casks shipped for the Proposed Action (DIRS 181377-BSC 2007,

Table G-9. Population escalation factors for 2000 to 2067.

States and counties	Population escalation factors	States and counties	Population escalation factors
Alabama	1.2277	Ohio	1.0174
Arkansas	1.4901	Oklahoma	1.3530
Arizona	4.9553	Oregon	2.2607
California	1.9439	Pennsylvania	1.0397
Colorado	1.9161	Rhode Island	1.0998
Connecticut	1.0831	South Carolina	1.6186
District of Columbia	0.7576	South Dakota	1.0604
Delaware	1.5200	Tennessee	1.7775
Florida	3.8088	Texas	2.8136
Georgia	2.1158	Utah	2.7680
Iowa	1.0099	Virginia	1.9803
Idaho	2.3948	Vermont	1.2790
Illinois	1.1383	Washington	2.5613
Indiana	1.2342	Wisconsin	1.2366
Kansas	1.1534	West Virginia	0.9511
Kentucky	1.2541	Wyoming	1.0591
Louisiana	1.1437	Nevada counties	
Massachusetts	1.1938	Churchill	2.2157
Maryland	1.7519	Clark	3.4982
Maine	1.1068	Elko	0.9005
Michigan	1.0760	Esmeralda	1.0219
Minnesota	1.6219	Eureka	0.7722
Missouri	1.3131	Humboldt	0.7332
Mississippi	1.1488	Lander	0.3521
Montana	1.2217	Lincoln	1.6673
North Carolina	2.4719	Lyon	4.8305
North Dakota	0.9445	Nye	3.9746
Nebraska	1.0965	Pershing	1.0541
New Hampshire	1.7545	Storey	2.9660
New Jersey	1.3217	Washoe	2.8725
New Mexico	1.1543	White Pine	0.6826
New York	1.0264	Mineral	0.7327

Section 7). Shipments of the 9,495 rail casks would use 2,833 trains. These estimates were based on 90-percent use of TAD canisters at the commercial sites.

G.5 Radionuclide Inventory

Appendix A of the Yucca Mountain FEIS (DIRS 155970-DOE 2002, pp. A-1 to A-71) provided the basis for the radionuclide inventory DOE used in the transportation analysis in the FEIS (DIRS 155970-DOE 2002, Chapter 6, Appendix J). Since the completion of the FEIS, DOE has updated these radionuclide inventories through additional data collection and analyses.

Table G-10. Updated cask shipment data.

Origin	Origin state	Fuel type	Mode	Casks containing uncanistered SNF	Casks containing TAD canisters	Casks containing other canisters	Total number of casks	Number of shipments
Browns Ferry	AL	BWR	Rail		245		245	82
Farley	AL	PWR	Rail		130		130	44
Arkansas	AR	PWR	Rail		107	20	127	43
Palo Verde	AZ	PWR	Rail		197	2	199	67
Diablo Canyon	CA	PWR	Rail		122		122	41
Humboldt Bay	CA	BWR	Rail			5	5	2
Rancho Seco	CA	PWR	Rail			21	21	7
San Onofre	CA	PWR	Rail		142	9	151	51
Haddam Neck	CT	PWR	Rail			40	40	14
Millstone	CT	BWR	Rail		66		66	22
Millstone	CT	PWR	Rail		110		110	37
Crystal River	FL	PWR	Truck	280			280	280
St. Lucie	FL	PWR	Rail		138		138	46
Turkey Point	FL	PWR	Truck	577			577	577
Hatch	GA	BWR	Rail		177		177	59
Vogtle	GA	PWR	Rail		115		115	39
Arnold	IA	BWR	Rail		58		58	20
Idaho National Laboratory	ID	BWR	Rail			2	2	1
Idaho National Laboratory	ID	DOE	Rail			179	179	36
Idaho National Laboratory	ID	Navy	Rail			400	400	80
Idaho National Laboratory	ID	PWR	Rail			7	7	2
Idaho National Laboratory	ID	HLW	Rail			106	106	22
Idaho National Laboratory	ID	BWR	Truck	1			1	1
Braidwood	IL	PWR	Rail		112		112	38
Byron	IL	PWR	Rail		122		122	41
Clinton	IL	BWR	Truck	327			327	327
Dresden	IL	BWR	Rail		181	14	195	65
LaSalle	IL	BWR	Rail		152		152	51
Morris	IL	BWR	Rail		67		67	23
Morris	IL	PWR	Rail		17		17	6
Quad Cities	IL	BWR	Rail		189		189	63
Zion	IL	PWR	Rail		106		106	36
Wolf Creek	KS	PWR	Rail		60		60	20
River Bend	LA	BWR	Rail		70		70	24
Waterford	LA	PWR	Rail		63		63	21
Pilgrim	MA	BWR	Truck	344			344	344

Table G-10. Updated cask shipment data (continued).

Origin	Origin state	Fuel type	Mode	Casks containing uncanistered SNF	Casks containing TAD canisters	Casks containin g other canisters	Total number of casks	Number of shipments
Yankee Rowe	MA	PWR	Rail			15	15	5
Calvert Cliffs	MD	PWR	Rail		126	12	138	46
Maine Yankee	ME	PWR	Rail			60	60	20
Big Rock Point	MI	BWR	Rail			7	7	3
Cook	MI	PWR	Truck	768			768	768
Fermi	MI	BWR	Rail		63		63	21
Palisades	MI	PWR	Rail		50	12	62	21
Monticello	MN	BWR	Rail		44		44	15
Prairie Island	MN	PWR	Rail		109		109	37
Callaway	MO	PWR	Rail		73		73	25
Grand Gulf	MS	BWR	Rail		100		100	34
Brunswick	NC	BWR	Rail		83	1	84	28
Brunswick	NC	PWR	Rail		15		15	5
Harris	NC	BWR	Rail		64		64	22
Harris	NC	PWR	Rail		64		64	22
McGuire	NC	PWR	Rail		152		152	51
Cooper	NE	BWR	Rail		49		49	17
Fort Calhoun	NE	PWR	Rail		50		50	17
Seabrook	NH	PWR	Rail		50		50	17
Hope Creek	NJ	BWR	Rail		79		79	27
Oyster Creek	NJ	BWR	Rail		79		79	27
Salem	NJ	PWR	Rail		118		118	40
FitzPatrick	NY	BWR	Rail		76		76	26
Ginna	NY	PWR	Truck	313			313	313
Indian Point	NY	PWR	Rail		133		133	45
Nine Mile Point	NY	BWR	Rail		147		147	49
West Valley	NY	HLW	Rail			56	56	12
Davis-Besse	OH	PWR	Rail		51		51	17
Perry	OH	BWR	Rail		75		75	25
Trojan	OR	PWR	Rail			33	33	11
Beaver Valley	PA	PWR	Rail		102		102	34
Limerick	PA	BWR	Rail		155		155	52
Peach Bottom	PA	BWR	Rail		206		206	69
Susquehanna	PA	BWR	Rail		162		162	54
Three Mile Island	PA	PWR	Rail		53		53	18
Catawba	SC	PWR	Rail		123		123	41
Oconee	SC	PWR	Rail		138	48	186	62
Robinson	SC	PWR	Rail		26	5	31	11
Savannah River Site	SC	DOE	Rail			45	45	9

Table G-10. Updated cask shipment data (continued).

Origin	Origin state	Fuel type	Mode	Casks containing uncanistered SNF	Casks containing TAD canisters	Casks containing other canisters	Total number of casks	Number of shipments
Savannah River Site	SC	HLW	Rail			698	698	140
Summer	SC	PWR	Rail		55		55	19
Sequoyah	TN	PWR	Rail		120		120	40
Watts Bar	TN	PWR	Rail		30		30	10
Comanche Peak	TX	PWR	Rail		99		99	33
South Texas	TX	PWR	Rail		95		95	32
North Anna	VA	PWR	Rail		117		117	39
Surry	VA	PWR	Rail		121		121	41
Vermont Yankee	VT	BWR	Rail		74		74	25
Columbia	WA	BWR	Rail		66	3	69	23
Hanford Site	WA	DOE	Rail			141	141	29
Hanford Site	WA	HLW	Rail			1064	1064	213
Hanford Site	WA	BWR	Truck	1			1	1
Hanford Site	WA	PWR	Truck	2			2	2
Kewaunee	WI	PWR	Rail		54		54	18
LaCrosse	WI	BWR	Truck	37			37	37
Point Beach	WI	PWR	Rail		98		98	33

Source: DIRS 181377-BSC 2007, Section 7.
BWR = Boiling-water reactor (commercial spent nuclear fuel).
DOE = U.S. Department of Energy spent nuclear fuel.
HLW = High-level radioactive waste.
PWR = Pressurized-water reactor (commercial spent nuclear fuel).
SNF= Spent nuclear fuel.

The primary sources of the new radionuclide inventory information are:

- *PWR Source Term Generation and Evaluation* (DIRS 169061-BSC 2004, all),
- *BWR Source Term Generation and Evaluation* (DIRS 164364-BSC 2003, all),
- *Source Term Estimates for DOE Spent Nuclear Fuels* (DIRS 169354-DOE 2004, all), and
- *Recommended Values for HLW Glass for Consistent Usage on the Yucca Mountain Project* (DIRS 180471-BSC 2007, all).

The radionuclide inventory DOE used in this Repository SEIS represents the radioactivity contained in about 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste that would be shipped to the repository. Tables G-11 through G-16 list the updated radionuclide inventories.

DOE spent nuclear fuel was organized into 34 groups based on the fuel compound, fuel enrichment, fuel cladding material, and fuel cladding condition (DIRS 171271-DOE 2004, all). The characteristics of the spent nuclear fuel, including percent enrichment, decay time, and burnup, would affect the radionuclide

Table G-11. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 1 through 8.

	Uranium metal				Uranium oxide			
					Zirconium clad (intact)			Stainless-steel/Hastelloy clad (intact)
Radionuclide	Zirconium-clad LEU Group	Non-Zirconium-clad LEU Group 2	Uranium-zirconium Group 3	Uranium-molybdenum Group 4	HEU Group 5	MEU Group 6	LEU Group 7	HEU Group 8
Actinium-227	5.0×10^{-3}	5.8×10^{-4}	3.0×10^{-3}	8.4×10^{-3}	5.4×10^{-3}	2.9×10^{-5}	4.2×10^{-3}	1.0×10^{-4}
Americium-241	7.1×10^{5}	2.1×10^{4}	1.4×10^{4}	1.8×10^{2}	4.6×10^{2}	4.8×10^{3}	3.7×10^{5}	4.6×10^{-1}
Americium-242m	4.4×10^{2}	3.4×10^{1}	2.2	2.8×10^{-2}	8.6×10^{-1}	9.7	7.8×10^{2}	3.5×10^{-5}
Americium-243	3.7×10^{2}	6.4	1.3	1.6×10^{-2}	1.8	2.1×10^{1}	1.7×10^{3}	4.1×10^{-6}
Carbon-14	1.1×10^{3}	2.0×10^{3}	7.0×10^{2}	1.1×10^{1}	5.3×10^{1}	1.6	6.6×10^{2}	9.5×10^{-1}
Chlorine-36	5.2×10^{-2}	3.7×10^{1}	1.2×10^{-3}	4.8×10^{-3}	2.8×10^{-1}	2.7×10^{-2}	2.1	5.1×10^{-3}
Curium-243	1.7×10^{1}	6.6	3.1×10^{-1}	4.0×10^{-3}	7.5×10^{-1}	8.7	7.6×10^{2}	9.8×10^{-7}
Curium-244	6.5×10^{3}	8.9×10^{1}	6.5	8.3×10^{-2}	1.5×10^{2}	1.7×10^{3}	1.6×10^{5}	8.9×10^{-6}
Cobalt-60	2.7×10^{4}	4.6×10^{5}	4.0×10^{4}	6.8×10^{2}	1.6×10^{4}	1.2×10^{2}	4.7×10^{4}	2.5×10^{2}
Cesium-134	1.1×10^{2}	1.5×10^{2}	5.0	1.2×10^{-1}	1.8	1.9×10^{1}	2.6×10^{3}	1.0×10^{-2}
Cesium-135	7.6×10^{1}	1.9	5.0	4.0	7.0	4.9×10^{-1}	4.2×10^{1}	1.3×10^{-1}
Cesium-137	9.3×10^{6}	2.2×10^{5}	9.0×10^{5}	1.3×10^{5}	3.4×10^{5}	4.8×10^{4}	4.9×10^{6}	5.7×10^{3}
Europium-154	5.2×10^{4}	1.2×10^{3}	4.2×10^{3}	6.9×10^{1}	2.3×10^{2}	7.8×10^{2}	9.1×10^{4}	2.4
Europium-155	2.5×10^{3}	7.7×10^{2}	3.9×10^{2}	1.3×10^{2}	1.7×10^{2}	8.5×10^{1}	1.2×10^{4}	2.5
Iron-55	4.7×10^{1}	6.2×10^{3}	3.7×10^{1}	1.7	2.8×10^{2}	6.8	1.1×10^{3}	4.2
Hydrogen-3	2.6×10^{4}	4.2×10^{3}	1.5×10^{4}	4.9×10^{2}	6.5×10^{2}	7.6×10^{2}	8.7×10^{4}	9.4
Iodine-129	6.5	1.3×10^{-1}	4.7×10^{-1}	1.1×10^{-1}	1.7×10^{-1}	3.3×10^{-2}	2.9	3.0×10^{-3}
Krypton-85	2.1×10^{5}	7.5×10^{3}	2.4×10^{4}	3.7×10^{3}	9.6×10^{3}	1.0×10^{3}	1.3×10^{5}	1.5×10^{2}
Neptunium-237	6.4×10^{1}	1.9	3.5	3.3×10^{-1}	3.0×10^{-1}	3.8×10^{-1}	3.1×10^{1}	4.8×10^{-3}
Protactinium-231	1.2×10^{-2}	1.1×10^{-3}	5.0×10^{-3}	1.7×10^{-2}	1.0×10^{-2}	4.3×10^{-5}	6.9×10^{-3}	2.0×10^{-4}
Lead-210	2.0×10^{-3}	3.6×10^{-4}	2.7×10^{-3}	3.5×10^{-5}	3.7×10^{-7}	2.7×10^{-6}	2.2×10^{-3}	3.1×10^{-9}
Promethium-147	4.7×10^{3}	1.6×10^{4}	6.2×10^{2}	1.1×10^{2}	2.8×10^{2}	5.6×10^{1}	8.9×10^{3}	4.0
Plutonium-238	1.5×10^{5}	3.6×10^{3}	4.0×10^{3}	6.5×10^{1}	2.9×10^{2}	2.5×10^{3}	2.1×10^{5}	1.2
Plutonium-239	2.2×10^{5}	7.1×10^{3}	1.2×10^{4}	1.8×10^{3}	2.0×10^{2}	3.9×10^{2}	4.0×10^{4}	2.8
Plutonium-240	1.7×10^{5}	3.5×10^{3}	5.2×10^{3}	7.1×10^{1}	7.3×10^{1}	5.1×10^{2}	4.4×10^{4}	3.6×10^{-1}
Plutonium-241	4.5×10^{6}	1.4×10^{5}	9.1×10^{4}	1.1×10^{3}	3.5×10^{3}	3.2×10^{4}	3.2×10^{6}	2.7
Plutonium-242	1.1×10^{2}	1.9	1.3	1.6×10^{-2}	1.9×10^{-1}	2.2	1.7×10^{2}	8.2×10^{-6}

Table G-11. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 1 through 8 (continued).

	Uranium metal				Uranium oxide			
					Zirconium clad (intact)			Stainless-steel/Hastelloy clad (intact)
Radionuclide	Zirconium-clad LEU Group 1	Non-Zirconium-clad LEU Group 2	Uranium-zirconium Group 3	Uranium-molybdenum Group 4	HEU Group 5	MEU Group 6	LEU Group 7	HEU Group 8
Radium-226	5.6×10^{-3}	9.7×10^{-4}	7.4×10^{-3}	9.4×10^{-5}	1.0×10^{-6}	7.3×10^{-6}	6.0×10^{-3}	8.2×10^{-9}
Radium-228	4.9×10^{-4}	2.4×10^{-5}	7.4×10^{-4}	1.1×10^{-5}	1.9×10^{-6}	1.8×10^{-7}	5.7×10^{-4}	3.4×10^{-8}
Ruthenium-106	4.4×10^{-3}	1.1×10^{3}	2.1×10^{-4}	2.9×10^{-5}	2.1×10^{-3}	2.6×10^{-1}	5.1×10^{2}	6.3×10^{-7}
Selenium-79	8.4×10^{1}	3.1	7.8	1.5	3.1	4.2×10^{-1}	3.9×10^{1}	5.5×10^{-2}
Tin-126	6.6	2.5	7.5	3.4	2.7	8.5×10^{-1}	7.2×10^{1}	4.8×10^{-2}
Strontium-90	6.7×10^{6}	1.6×10^{5}	7.9×10^{5}	1.1×10^{5}	3.2×10^{5}	3.2×10^{4}	3.4×10^{6}	5.4×10^{3}
Technetium-99	2.8×10^{3}	5.9×10^{1}	2.8×10^{2}	4.2×10^{1}	1.1×10^{2}	1.3×10^{1}	1.2×10^{3}	1.9
Thorium-229	1.8×10^{-3}	1.8×10^{-4}	2.7×10^{-3}	3.8×10^{-5}	3.7×10^{-6}	4.0×10^{-6}	2.3×10^{-3}	6.4×10^{-8}
Thorium-230	5.6×10^{-1}	8.8×10^{-2}	6.7×10^{-1}	8.6×10^{-3}	9.6×10^{-5}	6.9×10^{-4}	5.5×10^{-1}	7.3×10^{-7}
Thorium-232	4.9×10^{-4}	2.4×10^{-5}	7.5×10^{-4}	1.1×10^{-5}	1.9×10^{-6}	1.8×10^{-7}	5.8×10^{-4}	3.5×10^{-8}
Thallium-208	3.0×10^{-2}	2.0×10^{-2}	2.9×10^{-2}	8.7×10^{-4}	5.5×10^{-3}	6.0×10^{-3}	5.1×10^{-1}	8.8×10^{-5}
Uranium-232	8.2×10^{-2}	5.4×10^{-2}	7.8×10^{-2}	2.3×10^{-3}	1.5×10^{-2}	1.6×10^{-2}	1.4	2.4×10^{-4}
Uranium-233	3.9×10^{-1}	3.9×10^{-2}	5.7×10^{-1}	8.0×10^{-3}	8.0×10^{-4}	8.5×10^{-4}	5.0×10^{-1}	1.3×10^{-5}
Uranium-234	1.4×10^{3}	1.9×10^{2}	1.5×10^{3}	1.9×10^{1}	2.6×10^{-1}	1.7	1.2×10^{3}	1.6×10^{-3}
Uranium-235	4.8×10^{1}	8.2×10^{-2}	6.0×10^{-3}	2.0	9.9×10^{-1}	2.0×10^{-1}	2.3	3.9×10^{-1}
Uranium-236	9.7×10^{1}	2.8	1.7×10^{1}	1.3	3.7	2.6×10^{-1}	3.3×10^{1}	6.7×10^{-2}
Uranium-238	7.0×10^{2}	2.1	3.3×10^{-1}	1.0	2.1×10^{-2}	6.0×10^{-1}	3.0×10^{1}	4.7×10^{-3}

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
HEU = Highly enriched uranium.
LEU = Low-enriched uranium.
MEU = Medium-enriched uranium.

Table G-12. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 9 through 16.

	Uranium oxide							
	Stainless-steel clad (Intact)		Non-aluminum clad Non-intact or declad			Aluminum clad		Uranium-aluminum
Radionuclide	HEU Group 9	LEU Group 10	HEU Group 11	MEU Group 12	LEU Group 13	HEU Group 14	MEU and LEU Group 15	HEU Group 16
Actinium-227	1.4×10^{-4}	9.5×10^{-4}	5.6×10^{-3}	8.5×10^{-4}	4.2×10^{-3}	8.8×10^{-4}	1.3×10^{-5}	1.0×10^{-3}
Americium-241	1.1	1.8×10^{4}	1.9×10^{4}	1.5×10^{3}	4.7×10^{4}	4.9×10^{3}	4.8×10^{1}	5.2×10^{3}
Americium-242m	1.1×10^{-4}	8.8	3.8×10^{1}	3.0	1.1×10^{2}	9.9×10^{-1}	1.6×10^{-2}	1.6
Americium-243	1.2×10^{-5}	4.5	3.7×10^{1}	6.5	2.3×10^{2}	1.5×10^{1}	5.4×10^{-2}	1.8×10^{1}
Carbon-14	2.7	1.9×10^{3}	2.8×10^{2}	1.5×10^{1}	8.5×10^{1}	1.6×10^{-2}	2.1×10^{-4}	3.0×10^{-1}
Chlorine-36	1.5×10^{-2}	3.6×10^{1}	5.2	8.4×10^{-2}	6.5×10^{-1}	1.7×10^{-25}	4.7×10^{-28}	2.7×10^{-4}
Curium-243	4.2×10^{-6}	1.4	2.0	2.7	1.1×10^{2}	2.5	7.9×10^{-3}	3.7
Curium-244	4.9×10^{-5}	6.3×10^{1}	3.9×10^{2}	5.3×10^{2}	2.6×10^{4}	2.1×10^{3}	1.7	3.3×10^{3}
Cobalt-60	1.1×10^{4}	4.4×10^{5}	1.0×10^{5}	1.6×10^{4}	8.1×10^{4}	5.1×10^{1}	1.1	3.6×10^{2}
Cesium-134	1.7×10^{2}	5.2	6.8×10^{2}	7.1	4.4×10^{2}	7.4×10^{4}	1.3×10^{4}	1.3×10^{6}
Cesium-135	3.6×10^{-1}	1.1	1.8	2.0	1.4×10^{1}	5.5	1.2×10^{-1}	9.7
Cesium-137	2.4×10^{4}	1.6×10^{5}	1.0×10^{5}	1.3×10^{5}	1.2×10^{6}	3.2×10^{6}	9.6×10^{4}	6.9×10^{6}
Europium-154	3.2×10^{1}	8.1×10^{2}	3.0×10^{3}	3.3×10^{2}	1.7×10^{4}	5.9×10^{4}	2.5×10^{3}	2.1×10^{5}
Europium-155	1.3×10^{2}	2.4×10^{2}	6.1×10^{2}	2.0×10^{2}	3.4×10^{3}	2.0×10^{4}	1.1×10^{3}	1.1×10^{5}
Iron-55	8.5×10^{3}	4.6×10^{3}	3.5×10^{4}	1.1×10^{3}	5.4×10^{3}	4.6×10^{3}	1.9×10^{2}	3.7×10^{4}
Hydrogen-3	7.3×10^{1}	3.9×10^{3}	7.3×10^{2}	5.1×10^{2}	1.4×10^{4}	7.5×10^{3}	3.3×10^{2}	2.3×10^{4}
Iodine-129	8.7×10^{-3}	9.7×10^{-2}	4.4×10^{-2}	5.6×10^{-2}	5.7×10^{-1}	1.1	2.7×10^{-2}	2.0
Krypton-85	1.4×10^{3}	4.4×10^{3}	4.8×10^{3}	5.2×10^{3}	4.2×10^{4}	1.8×10^{5}	8.9×10^{3}	6.0×10^{5}
Neptunium-237	1.4×10^{-2}	1.7	4.5×10^{-1}	1.9×10^{-1}	4.1	2.2×10^{1}	3.4×10^{-1}	3.4×10^{1}
Protactinium-231	3.4×10^{-4}	2.0×10^{-3}	7.3×10^{-3}	2.0×10^{-3}	9.9×10^{-3}	2.7×10^{-3}	4.6×10^{-5}	3.5×10^{-3}
Lead-210	2.4×10^{-9}	3.5×10^{-4}	5.5×10^{-5}	8.4×10^{-7}	1.2×10^{-5}	6.4×10^{-5}	1.4×10^{-6}	8.7×10^{-5}
Promethium-147	7.5×10^{3}	1.7×10^{3}	3.0×10^{4}	1.0×10^{3}	6.6×10^{3}	1.4×10^{5}	7.1×10^{4}	4.2×10^{6}
Plutonium-238	3.9	3.1×10^{3}	7.1×10^{3}	8.0×10^{2}	2.9×10^{4}	7.8×10^{4}	7.2×10^{2}	1.1×10^{5}
Plutonium-239	8.0	5.7×10^{3}	9.7×10^{2}	1.6×10^{2}	4.4×10^{3}	7.4×10^{2}	1.5×10^{1}	1.3×10^{3}
Plutonium-240	1.0	2.3×10^{3}	6.7×10^{2}	1.6×10^{2}	5.5×10^{3}	4.1×10^{2}	8.8	7.1×10^{2}
Plutonium-241	1.8×10^{1}	1.2×10^{5}	1.1×10^{5}	1.0×10^{4}	5.2×10^{5}	1.0×10^{5}	2.2×10^{3}	2.3×10^{5}
Plutonium-242	2.4×10^{-5}	1.4	5.6	6.7×10^{-1}	2.3×10^{1}	1.5	1.3×10^{-2}	2.0

Table G-12. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 9 through 16 (continued).

	Uranium oxide							Uranium-aluminum
	Stainless-steel Clad (intact)		Non-aluminum clad Non-intact or declad			Aluminum clad		
Radionuclide	HEU Group 9	LEU Group 10	HEU Group 11	MEU Group 12	LEU Group 13	HEU Group 14	MEU and LEU Group 15	HEU Group 16
Radium-226	8.5×10^{-9}	9.4×10^{-4}	1.5×10^{-4}	2.3×10^{-6}	4.2×10^{-5}	2.9×10^{-4}	4.8×10^{-6}	3.6×10^{-4}
Radium-228	9.2×10^{-8}	1.9×10^{-5}	1.4×10^{-3}	5.6×10^{-7}	4.3×10^{-6}	1.9×10^{-8}	2.3×10^{-10}	1.2×10^{-6}
Ruthenium-106	3.8×10^{2}	2.1	1.6×10^{3}	3.3×10^{-2}	2.7×10^{-1}	1.6×10^{3}	5.1×10^{3}	3.6×10^{5}
Selenium-79	1.6×10^{-1}	2.7	7.9×10^{-1}	9.5×10^{-1}	8.3	1.9×10^{1}	4.7×10^{-1}	3.4×10^{1}
Tin-126	1.4×10^{-1}	2.0	6.9×10^{-1}	9.8×10^{-1}	1.2×10^{1}	1.7×10^{1}	4.2×10^{-1}	3.0×10^{1}
Strontium-90	2.3×10^{4}	1.2×10^{5}	9.6×10^{4}	1.2×10^{5}	9.3×10^{5}	3.0×10^{6}	9.2×10^{4}	6.5×10^{6}
Technetium-99	5.6	4.7×10^{1}	2.8×10^{1}	3.3×10^{1}	2.8×10^{2}	6.2×10^{2}	1.5×10^{1}	1.1×10^{3}
Thorium-229	1.0×10^{-7}	1.7×10^{-4}	4.0×10^{-3}	1.8×10^{-6}	3.4×10^{-5}	7.6×10^{-6}	1.1×10^{-7}	9.7×10^{-6}
Thorium-230	1.2×10^{-6}	8.6×10^{-2}	1.3×10^{-2}	2.2×10^{-4}	5.3×10^{-3}	5.2×10^{-2}	9.1×10^{-4}	6.8×10^{-2}
Thorium-232	9.9×10^{-8}	1.9×10^{-5}	1.4×10^{-3}	5.7×10^{-7}	4.4×10^{-6}	2.9×10^{-8}	4.2×10^{-10}	1.5×10^{-6}
Thallium-208	2.9×10^{-4}	1.3×10^{-2}	2.0×10^{-1}	3.3×10^{-3}	7.6×10^{-2}	7.0×10^{-2}	1.6×10^{-3}	1.2×10^{-1}
Uranium-232	8.0×10^{-4}	3.6×10^{-2}	5.4×10^{-1}	9.0×10^{-3}	2.1×10^{-1}	1.9×10^{-1}	4.7×10^{-3}	3.4×10^{-1}
Uranium-233	3.7×10^{-5}	3.6×10^{-2}	8.2×10^{-1}	4.5×10^{-4}	9.7×10^{-3}	4.2×10^{-3}	7.8×10^{-5}	6.7×10^{-3}
Uranium-234	4.4×10^{-3}	1.9×10^{2}	2.9×10^{1}	5.4×10^{-1}	1.7×10^{1}	2.3×10^{2}	6.6	4.3×10^{2}
Uranium-235	2.7×10^{-1}	1.8×10^{-1}	2.4	1.3×10^{-1}	4.6	7.8	6.2×10^{-2}	1.3×10^{1}
Uranium-236	1.9×10^{-1}	2.6	9.8×10^{-1}	1.1	7.5	2.4×10^{1}	5.6×10^{-1}	4.2×10^{1}
Uranium-238	1.9×10^{-1}	2.6×10^{-1}	3.6×10^{-1}	1.3×10^{-1}	2.7×10^{1}	1.3×10^{-1}	8.3×10^{-2}	3.2×10^{-1}

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
HEU= Highly enriched uranium.
LEU = Low-enriched uranium.
MEU= Medium-enriched uranium.

Table G-13. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 17 through 24.

			Thorium/uranium carbide		Plutonium/ uranium carbide	Mixed oxide		
Radionuclide	Uranium-aluminum MEU Group 17	Uranium silicide Group 18	TRISO or BISO particles in graphite Group 19	Mono-pyrolytic carbon particles Group 20	Non-graphite non-sodium bonded Group 21	Zirconium clad Group 22	Stainless-steel clad Group 23	Non-stainless steel Non-zirconium clad Group 24
Actinium-227	6.1×10^{-5}	2.7×10^{-4}	2.6	2.3×10^{-1}	2.1×10^{-8}	1.6×10^{-1}	4.2×10^{-2}	4.9×10^{-3}
Americium-241	1.9×10^{3}	8.6×10^{3}	2.3×10^{3}	1.8×10^{2}	8.9×10^{2}	5.8×10^{5}	2.5×10^{5}	3.0×10^{4}
Americium-242m	1.3	6.1	2.2	1.4×10^{-1}	1.7×10^{1}	1.2×10^{3}	2.1×10^{3}	2.8×10^{2}
Americium-243	1.1	4.4	4.0×10^{1}	2.7	9.0×10^{-1}	1.1×10^{3}	4.4×10^{2}	6.1×10^{1}
Carbon-14	3.0×10^{-2}	1.2	2.0×10^{1}	1.4	2.2×10^{-1}	8.3×10^{3}	2.6×10^{3}	3.7×10^{2}
Chlorine-36	2.5×10^{-5}	1.2×10^{-3}	9.2×10^{-1}	6.2×10^{-2}	2.9×10^{-6}	1.6×10^{2}	4.9×10^{1}	7.0
Curium-243	4.3×10^{-1}	2.0	3.0×10^{1}	1.5	4.9	7.7×10^{1}	5.8×10^{2}	7.4×10^{1}
Curium-244	3.3×10^{1}	1.3×10^{2}	9.0×10^{3}	3.8×10^{2}	2.1×10^{1}	1.2×10^{4}	7.7×10^{3}	1.2×10^{3}
Cobalt-60	3.0×10^{1}	9.1×10^{2}	2.3×10^{3}	2.7×10^{1}	8.9×10^{1}	1.9×10^{6}	3.5×10^{6}	6.4×10^{5}
Cesium-134	1.3×10^{5}	2.6×10^{5}	3.7×10^{3}	1.5×10^{1}	2.0×10^{2}	9.4×10^{1}	4.1×10^{4}	5.1×10^{3}
Cesium-135	1.3	4.8	2.1×10^{1}	1.4	4.0×10^{-1}	3.2×10^{1}	4.9×10^{1}	6.4
Cesium-137	9.1×10^{5}	2.5×10^{6}	1.5×10^{6}	7.8×10^{4}	1.6×10^{4}	1.5×10^{6}	2.3×10^{6}	3.2×10^{5}
Europium-154	2.4×10^{4}	9.2×10^{4}	3.9×10^{4}	9.3×10^{2}	3.0×10^{2}	8.6×10^{4}	1.1×10^{5}	1.8×10^{4}
Europium-155	1.1×10^{4}	3.7×10^{4}	5.9×10^{3}	6.3×10^{1}	3.8×10^{2}	5.3×10^{3}	6.7×10^{4}	9.0×10^{3}
Iron-55	1.0×10^{4}	4.7×10^{4}	1.6	5.3×10^{-3}	2.6×10^{1}	2.0×10^{4}	4.8×10^{5}	5.5×10^{4}
Hydrogen-3	3.3×10^{3}	8.8×10^{3}	6.9×10^{3}	2.3×10^{2}	6.0×10^{1}	1.7×10^{4}	1.7×10^{4}	2.7×10^{3}
Iodine-129	2.4×10^{-1}	6.6×10^{-1}	8.7×10^{-1}	5.9×10^{-2}	1.1×10^{-2}	7.8×10^{-1}	1.3	1.7×10^{-1}
Krypton-85	8.7×10^{4}	2.2×10^{5}	7.9×10^{4}	2.3×10^{3}	4.7×10^{2}	4.2×10^{4}	8.5×10^{4}	1.2×10^{4}
Neptunium-237	2.3	4.7	1.1×10^{1}	7.3×10^{-1}	2.5×10^{-2}	1.1×10^{1}	5.6	7.6×10^{-1}
Protactinium-231	3.4×10^{-4}	1.2×10^{-3}	4.1	2.8×10^{-1}	5.7×10^{-8}	2.0×10^{-1}	6.1×10^{-2}	8.7×10^{-3}
Lead-210	1.0×10^{-6}	1.2×10^{-5}	7.3×10^{-4}	8.3×10^{-5}	4.1×10^{-9}	1.6×10^{-3}	3.2×10^{-4}	1.1×10^{-5}
Promethium-147	7.5×10^{5}	1.8×10^{6}	5.2×10^{3}	1.7×10^{1}	1.1×10^{3}	1.9×10^{3}	2.2×10^{5}	2.8×10^{4}
Plutonium-238	4.8×10^{3}	8.8×10^{3}	1.5×10^{5}	9.5×10^{3}	2.2×10^{2}	1.5×10^{5}	3.8×10^{4}	3.0×10^{3}
Plutonium-239	1.3×10^{3}	6.7×10^{3}	1.2×10^{2}	7.9	1.0×10^{3}	2.2×10^{4}	1.5×10^{5}	0.0

Table G-13. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 17 through 24 (continued).

			Thorium/uranium carbide		Plutonium/ uranium carbide	Mixed oxide		
Radionuclide	Uranium-aluminum MEU Group 17	Uranium silicide Group 18	TRISO or BISO particles in graphite Group 19	Mono-pyrolytic carbon particles Group 20	Non-graphite non-sodium bonded Group 21	Zirconium clad Group 22	Stainless-steel clad Group 23	Non-stainless steel non-zirconium clad Group 24
Plutonium-240	7.1×10^{2}	3.5×10^{3}	2.2×10^{2}	1.6×10^{1}	8.4×10^{2}	1.3×10^{4}	1.1×10^{5}	3.9×10^{3}
Plutonium-241	1.0×10^{5}	4.9×10^{5}	3.1×10^{4}	1.1×10^{3}	2.3×10^{4}	1.3×10^{6}	4.2×10^{6}	2.6×10^{4}
Plutonium-242	4.5×10^{-1}	2.0	3.4	2.3×10^{-1}	2.7×10^{-1}	1.3×10^{2}	4.4×10^{1}	1.8
Radium-226	9.0×10^{-6}	4.7×10^{-5}	1.2×10^{-3}	1.6×10^{-4}	1.5×10^{-8}	4.4×10^{-3}	9.2×10^{-4}	5.1×10^{-5}
Radium-228	1.2×10^{-7}	4.9×10^{-6}	7.8×10^{-1}	5.4×10^{-2}	8.1×10^{-13}	4.1×10^{-2}	1.2×10^{-2}	1.7×10^{-3}
Ruthenium-106	6.4×10^{4}	1.7×10^{5}	6.5×10^{-1}	7.9×10^{-2}	5.9×10^{1}	7.4×10^{-1}	1.2×10^{4}	1.5×10^{3}
Selenium-79	4.1	1.1×10^{1}	1.8×10^{1}	1.2	8.5×10^{-2}	1.4×10^{1}	1.3×10^{1}	1.7
Tin-126	3.7	1.0×10^{1}	1.9×10^{1}	1.3	3.7×10^{-1}	1.3×10^{1}	4.0×10^{1}	5.2
Strontium-90	8.6×10^{5}	2.3×10^{6}	1.5×10^{6}	7.4×10^{4}	5.8×10^{3}	1.4×10^{6}	1.2×10^{6}	1.7×10^{5}
Technetium-99	1.4×10^{2}	3.9×10^{2}	2.9×10^{2}	1.9×10^{1}	3.3	4.8×10^{2}	4.8×10^{2}	6.2×10^{1}
Thorium-229	5.5×10^{-7}	5.1×10^{-6}	5.8	6.2×10^{-1}	1.6×10^{-8}	1.2×10^{-1}	2.9×10^{-2}	2.7×10^{-3}
Thorium-230	3.6×10^{-3}	8.4×10^{-3}	1.2×10^{-1}	1.1×10^{-2}	3.1×10^{-6}	4.0×10^{-1}	9.6×10^{-2}	9.1×10^{-3}
Thorium-232	1.4×10^{-7}	6.4×10^{-6}	2.5	1.7×10^{-1}	1.2×10^{-12}	4.1×10^{-2}	1.3×10^{-2}	1.8×10^{-3}
Thallium-208	9.8×10^{-3}	1.7×10^{-2}	5.8×10^{2}	3.5×10^{1}	4.3×10^{-3}	6.0	2.5	3.7×10^{-1}
Uranium-232	2.9×10^{-2}	4.8×10^{-2}	1.6×10^{3}	9.4×10^{1}	1.2×10^{-2}	1.6×10^{1}	6.7	1.0
Uranium-233	5.0×10^{-4}	4.3×10^{-3}	1.8×10^{3}	1.2×10^{2}	2.5×10^{-6}	2.5×10^{1}	7.7	1.1
Uranium-234	3.7×10^{1}	4.7×10^{1}	2.4×10^{2}	1.7×10^{1}	2.2×10^{-2}	8.7×10^{2}	2.7×10^{2}	3.9×10^{1}
Uranium-235	4.4×10^{-1}	1.2	3.6	2.4×10^{-1}	1.9×10^{-4}	4.0×10^{1}	1.2×10^{1}	1.8
Uranium-236	4.7	1.2×10^{1}	7.4	5.0×10^{-1}	1.1×10^{-3}	1.6×10^{1}	5.1	7.3×10^{-1}
Uranium-238	7.9×10^{-1}	2.2	4.5×10^{-2}	3.0×10^{-3}	1.8×10^{-2}	8.0	5.0	3.9×10^{-1}

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
HEU= Highly enriched uranium.
LEU = Low-enriched uranium.
MEU= Medium-enriched uranium.

Table G-14. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 25 through 30, 32, and 34.

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/Incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25	Stainless-steel clad Group 26	HEU Group 27	MEU Group 28	MEU Group 29	Declad Group 30	Naval spent nuclear fuel Group 32[a]	Miscellaneous Group 34
Actinium-227	3.9×10^{1}	7.4	2.1×10^{-5}	6.5×10^{-5}	2.1×10^{-5}	2.7×10^{-4}	3.9×10^{-2}	5.0×10^{-3}
Americium-241	1.1×10^{2}	7.1×10^{3}	3.8×10^{2}	1.1×10^{2}	3.0×10^{1}	1.1×10^{2}	2.0×10^{4}	2.7×10^{3}
Americium-242m	7.3×10^{-1}	1.6×10^{1}	8.2×10^{-1}	7.2×10^{-2}	1.9×10^{-2}	3.3×10^{-2}	1.8×10^{2}	6.9
Americium-243	1.5×10^{-1}	1.5×10^{1}	1.1	7.7×10^{-3}	2.4×10^{-3}	4.2×10^{-3}	2.7×10^{2}	1.5×10^{1}
Carbon-14	4.4×10^{1}	1.2×10^{2}	4.4	6.7	4.4×10^{-1}	3.6	6.4×10^{3}	3.9×10^{1}
Californium-252	0.0	0.0	0.0	0.0	0.0	0.0	4.8×10^{-4}	0.0
Chlorine-36	8.5×10^{-1}	2.2	9.3×10^{-2}	1.5×10^{-1}	4.3×10^{-4}	8.0×10^{-2}	2.8×10^{2}	7.0×10^{-1}
Curium-242	0.0	0.0	0.0	0.0	0.0	0.0	5.6×10^{2}	0.0
Curium-243	1.8×10^{-1}	1.0	1.1	8.8×10^{-3}	2.4×10^{-3}	1.7×10^{-3}	3.2×10^{2}	8.1×10^{-1}
Curium-244	9.8	2.2×10^{2}	1.1×10^{2}	8.2×10^{-2}	2.6×10^{-2}	8.6×10^{-3}	2.5×10^{4}	5.4×10^{1}
Curium-245	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0
Curium-246	0.0	0.0	0.0	0.0	0.0	0.0	5.6×10^{-1}	0.0
Curium-247	0.0	0.0	0.0	0.0	0.0	0.0	3.8×10^{-6}	0.0
Curium-248	0.0	0.0	0.0	0.0	0.0	0.0	1.0×10^{-5}	0.0
Cobalt-60	1.5×10^{3}	9.5×10^{4}	2.3×10^{4}	5.8×10^{4}	2.2×10^{2}	9.8×10^{1}	1.5×10^{6}	1.1×10^{4}
Cobalt-60 (Crud)	0.0	0.0	0.0	0.0	0.0	0.0	2.3×10^{3}	0.0
Cesium-134	3.5×10^{2}	1.1×10^{1}	9.8×10^{3}	4.0×10^{3}	7.1×10^{2}	7.0×10^{-4}	3.4×10^{7}	8.8×10^{1}
Cesium-135	1.3×10^{1}	2.6	6.9×10^{-1}	1.7	3.2×10^{-1}	9.1×10^{-1}	1.8×10^{3}	4.4
Cesium-137	8.8×10^{5}	1.4×10^{5}	8.0×10^{4}	1.4×10^{5}	2.4×10^{4}	2.8×10^{4}	1.8×10^{8}	2.1×10^{5}
Europium-154	9.1×10^{3}	3.2×10^{3}	2.7×10^{3}	7.1×10^{2}	1.0×10^{4}	1.2×10^{1}	0.0	5.1×10^{2}
Europium-155	1.3×10^{3}	3.0×10^{2}	9.8×10^{2}	1.3×10^{3}	3.1×10^{3}	1.6	0.0	2.3×10^{3}
Iron-55	1.6×10^{1}	3.8×10^{3}	1.2×10^{4}	3.4×10^{4}	6.0×10^{1}	1.4×10^{-1}	0.0	3.7×10^{2}
Hydrogen-3	1.8×10^{3}	5.5×10^{2}	2.5×10^{2}	5.2×10^{2}	8.5×10^{1}	2.5×10^{1}	5.6×10^{5}	1.1×10^{3}
Iodine-129	7.5×10^{-1}	1.3×10^{-1}	2.5×10^{-2}	3.8×10^{-2}	7.4×10^{-3}	2.1×10^{-2}	4.8×10^{1}	1.1×10^{-1}
Krypton-85	5.6×10^{4}	5.8×10^{3}	5.8×10^{3}	1.2×10^{4}	1.9×10^{3}	3.9×10^{2}	1.4×10^{7}	1.3×10^{4}

Table G-14. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 25 through 30, 32, and 34 (continued).

	Thorium/uranium oxide		Uranium/zirconium hydride: Stainless steel/Incoloy clad		Uranium/zirconium hydride: Aluminum clad			
Radionuclide	Zirconium clad Group 25	Stainless-steel clad Group 26	HEU Group 27	MEU Group 28	MEU Group 29	Declad Group 30	Naval spent nuclear fuel Group 32[a]	Miscellaneous Group 34
Niobium-93m	0.0	0.0	0.0	0.0	0.0	0.0	1.4×10^{3}	0.0
Niobium-94	0.0	0.0	0.0	0.0	0.0	0.0	7.2×10^{4}	0.0
Nickel-59	0.0	0.0	0.0	0.0	0.0	0.0	2.5×10^{4}	0.0
Nickel-63	0.0	0.0	0.0	0.0	0.0	0.0	3.1×10^{6}	0.0
Neptunium-237	5.9×10^{-2}	1.5×10^{-1}	4.2×10^{-1}	6.5×10^{-2}	1.5×10^{-2}	3.7×10^{-2}	6.4×10^{2}	3.6×10^{-1}
Protactinium-231	5.7×10^{1}	9.1	5.3×10^{-5}	2.3×10^{-4}	5.6×10^{-5}	4.4×10^{-4}	2.1×10^{-1}	1.2×10^{-2}
Lead-210	5.6×10^{-3}	1.1×10^{-3}	1.9×10^{-8}	1.2×10^{-9}	9.8×10^{-10}	2.0×10^{-8}	3.6×10^{-4}	7.7×10^{-6}
Palladium-107	0.0	0.0	0.0	0.0	0.0	0.0	2.4×10^{1}	0.0
Promethium-147	1.7×10^{3}	2.3×10^{2}	1.8×10^{4}	9.3×10^{4}	1.4×10^{4}	4.1×10^{-1}	0.0	2.2×10^{4}
Plutonium-238	2.2×10^{2}	2.9×10^{3}	1.8×10^{3}	5.3×10^{1}	1.3×10^{1}	2.1×10^{1}	4.8×10^{6}	8.6×10^{2}
Plutonium-239	1.3×10^{1}	3.8×10^{2}	4.9×10^{1}	2.9×10^{2}	5.7×10^{1}	1.6×10^{2}	4.8×10^{3}	2.1×10^{3}
Plutonium-240	7.6	2.7×10^{2}	4.0×10^{1}	1.1×10^{2}	2.3×10^{1}	6.0×10^{1}	5.6×10^{3}	1.9×10^{2}
Plutonium-241	1.1×10^{3}	7.1×10^{4}	1.1×10^{4}	4.9×10^{3}	1.0×10^{3}	3.3×10^{2}	1.6×10^{6}	1.7×10^{4}
Plutonium-242	1.9×10^{-2}	2.2	1.7×10^{-1}	1.2×10^{-2}	3.1×10^{-3}	6.6×10^{-3}	3.2×10^{1}	7.2×10^{-1}
Radium-226	6.8×10^{-3}	1.7×10^{-3}	7.8×10^{-8}	5.4×10^{-9}	3.0×10^{-9}	4.8×10^{-8}	2.2×10^{-3}	2.0×10^{-5}
Radium-228	2.2	3.5×10^{-1}	7.3×10^{-7}	1.0×10^{-5}	2.0×10^{-6}	7.2×10^{-6}	7.2×10^{-5}	3.1×10^{-4}
Rhodium-102	0.0	0.0	0.0	0.0	0.0	0.0	1.1×10^{1}	0.0
Ruthenium-106	1.8×10^{-2}	3.5×10^{-3}	1.4×10^{3}	4.0×10^{3}	6.4×10^{2}	9.7×10^{-11}	2.4×10^{6}	3.9×10^{1}
Selenium-79	1.7×10^{1}	2.9	4.5×10^{-1}	6.8×10^{-1}	1.3×10^{-1}	3.7×10^{-1}	1.4×10^{2}	1.6
Samarium-151	0.0	0.0	0.0	0.0	0.0	0.0	5.6×10^{5}	0.0
Tin-126	1.9×10^{1}	3.2	4.2×10^{-1}	6.3×10^{-1}	1.2×10^{-1}	3.5×10^{-1}	4.8×10^{2}	3.6
Strontium-90	8.9×10^{5}	1.4×10^{5}	7.5×10^{4}	1.3×10^{5}	2.3×10^{4}	2.5×10^{4}	1.8×10^{8}	1.9×10^{5}
Technetium-99	1.5×10^{2}	3.1×10^{1}	1.4×10^{1}	2.3×10^{1}	4.4	1.3×10^{1}	2.8×10^{4}	4.5×10^{1}
Thorium-229	2.2×10^{1}	4.9	5.1×10^{-6}	9.0×10^{-6}	2.7×10^{-6}	2.2×10^{-5}	3.8×10^{-3}	1.8×10^{-3}

Table G-14. Radionuclide inventories (curies) for DOE spent nuclear fuel groups 25 through 30, 32, and 34 (continued).

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/Incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25	Stainless-steel clad Group 26	HEU Group 27	MEU Group 28	MEU Group 29	Declad Group 30	Naval spent nuclear fuel Group 32[a]	Miscellaneous Group 34
Thorium-230	4.9×10^{-1}	9.0×10^{-2}	1.6×10^{-5}	1.2×10^{-6}	4.1×10^{-7}	3.7×10^{-6}	7.2×10^{-1}	1.9×10^{-3}
Thorium-232	4.5	8.0×10^{-1}	8.5×10^{-7}	1.3×10^{-5}	2.4×10^{-6}	7.2×10^{-6}	9.2×10^{-5}	2.7×10^{-2}
Thallium-208	7.2×10^{3}	1.1×10^{3}	5.0×10^{-3}	8.7×10^{-4}	1.9×10^{-4}	3.4×10^{-4}	0.0	4.5×10^{-1}
Uranium-232	2.0×10^{4}	2.9×10^{3}	1.4×10^{-2}	2.5×10^{-3}	5.3×10^{-4}	9.1×10^{-4}	2.2×10^{2}	1.2
Uranium-233	1.4×10^{4}	2.5×10^{3}	2.4×10^{-3}	6.3×10^{-3}	1.3×10^{-3}	3.5×10^{-3}	1.2	8.7×10^{1}
Uranium-234	3.9×10^{2}	7.4×10^{1}	1.2×10^{-1}	8.7×10^{-3}	2.1×10^{-3}	8.1×10^{-3}	6.0×10^{3}	4.4
Uranium-235	3.0×10^{-2}	5.3×10^{-1}	2.1×10^{-1}	5.0×10^{-1}	1.3×10^{-1}	2.6×10^{-2}	1.2×10^{2}	2.1×10^{-1}
Uranium-236	6.3×10^{-2}	2.2×10^{-1}	4.7×10^{-1}	6.6×10^{-1}	1.3×10^{-1}	3.6×10^{-1}	1.0×10^{3}	1.3
Uranium-238	1.8×10^{-3}	1.1×10^{-1}	1.6×10^{-2}	3.9×10^{-1}	9.7×10^{-2}	1.5×10^{-2}	4.8×10^{-1}	8.6×10^{-2}
Zirconium-93	0.0	0.0	0.0	0.0	0.0	0.0	4.4×10^{3}	0.0

Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.
Note: There are no shipments of Group 31 and 33 spent nuclear fuel.
a. Radionuclide inventory is for 400 casks. Single cask naval spent fuel inventory is from DIRS 155857-McKenzie 2001, Table 3.
HEU= Highly enriched uranium.
LEU = Low-enriched uranium.
MEU= Medium-enriched uranium.

Table G-15. Radionuclide inventories (curies) for commercial spent nuclear fuel.

Radionuclide	BWR SNF inventory (Ci/assembly)[a]	BWR SNF total inventory[a]	PWR SNF inventory (Ci/assembly)[b]	PWR SNF total inventory[b]
Americium-241	3.73×10^{2}	4.84×10^{7}	1.28×10^{3}	1.21×10^{8}
Americium-242m	2.88	3.74×10^{5}	7.99	7.58×10^{5}
Americium-243	8.63	1.12×10^{6}	3.93×10^{1}	3.73×10^{6}
Carbon-14	1.69×10^{-1}	2.19×10^{4}	4.35×10^{-1}	4.13×10^{4}
Cadmium-113m	6.23	8.08×10^{5}	2.34×10^{1}	2.22×10^{6}
Cerium-144	1.73×10^{1}	2.24×10^{6}	6.99×10^{1}	6.63×10^{6}
Curium-242	2.38	3.09×10^{5}	6.60	6.26×10^{5}
Curium-243	5.55	7.20×10^{5}	2.48×10^{1}	2.35×10^{6}
Curium-244	9.23×10^{2}	1.20×10^{8}	5.85×10^{3}	5.55×10^{8}
Curium-245	9.07×10^{-2}	1.18×10^{4}	8.16×10^{-1}	7.74×10^{4}
Curium-246	4.26×10^{-2}	5.53×10^{3}	4.07×10^{-1}	3.86×10^{4}
Cobalt-60	1.14×10^{2}	1.48×10^{7}	2.17×10^{3}	2.06×10^{8}
Cobalt-60 (Crud)	5.66×10^{1}	7.34×10^{6}	1.69×10^{1}	1.60×10^{6}
Cesium-134	1.31×10^{3}	1.70×10^{8}	5.43×10^{3}	5.15×10^{8}
Cesium-137	2.41×10^{4}	3.13×10^{9}	7.16×10^{4}	6.79×10^{9}
Europium-154	7.79×10^{2}	1.01×10^{8}	3.01×10^{3}	2.85×10^{8}
Europium-155	1.93×10^{2}	2.51×10^{7}	6.42×10^{2}	6.09×10^{7}
Iron-55 (Crud)	9.84×10^{1}	1.28×10^{7}	2.09×10^{2}	1.98×10^{7}
Hydrogen-3	1.05×10^{2}	1.36×10^{7}	3.05×10^{2}	2.90×10^{7}
Iodine-129	9.22×10^{-3}	1.20×10^{3}	2.76×10^{-2}	2.62×10^{3}
Krypton-85	1.17×10^{3}	1.52×10^{8}	3.39×10^{3}	3.21×10^{8}
Neptunium-237	8.74×10^{-2}	1.13×10^{4}	2.94×10^{-1}	2.79×10^{4}
Promethium-147	2.11×10^{3}	2.74×10^{8}	6.06×10^{3}	5.75×10^{8}
Plutonium-238	1.02×10^{3}	1.32×10^{8}	3.98×10^{3}	3.77×10^{8}
Plutonium-239	5.41×10^{1}	7.02×10^{6}	1.75×10^{2}	1.66×10^{7}
Plutonium-240	1.27×10^{2}	1.65×10^{7}	3.63×10^{2}	3.44×10^{7}
Plutonium-241	1.57×10^{4}	2.04×10^{9}	5.64×10^{4}	5.35×10^{9}
Plutonium-242	7.08×10^{-1}	9.18×10^{4}	2.48	2.35×10^{5}
Ruthenium-106	9.05×10^{1}	1.17×10^{7}	4.04×10^{2}	3.83×10^{7}
Antimony-125	1.45×10^{2}	1.88×10^{7}	5.20×10^{2}	4.93×10^{7}
Strontium-90	1.66×10^{4}	2.15×10^{9}	4.51×10^{4}	4.28×10^{9}
Uranium-232	8.74×10^{-3}	1.13×10^{3}	3.61×10^{-2}	3.42×10^{3}
Uranium-234	2.39×10^{-1}	3.10×10^{4}	5.24×10^{-1}	4.97×10^{4}
Uranium-236	7.45×10^{-2}	9.66×10^{3}	1.77×10^{-1}	1.68×10^{4}
Uranium-238	6.24×10^{-2}	8.09×10^{3}	1.46×10^{-1}	1.38×10^{4}
Yttrium-90	1.66×10^{4}	2.15×10^{9}	4.51×10^{4}	4.28×10^{9}

Source: DIRS 169061-BSC 2004, all; DIRS 164364-BSC 2003, all.

a. Total inventory for pressurized water reactor spent nuclear fuel shipped in rail casks is based on 94,817 assemblies (calculated from rail and truck shipments and cask capacities from DIRS 181377-BSC 2007, Section 7).

b. Total inventory for boiling water reactor spent nuclear fuel shipped in rail casks is based on 129,721 assemblies (calculated from rail and truck shipments and cask capacities from DIRS 181377-BSC 2007, Section 7).

PWR = pressurized water reactor.
BWR = boiling water reactor.
SNF = spent nuclear fuel.

Table G-16. Radionuclide inventories (curies) for high-level radioactive waste.

Radionuclide	Hanford Site[a]	Idaho National Laboratory[b]	Savannah River Site[c]	West Valley[d]
Actinium-227	0.0	7.38×10^{1}	0.0	4.92×10^{1}
Americium-241	5.41×10^{3}	1.08×10^{5}	7.98×10^{5}	4.58×10^{4}
Americium-242	7.86×10^{-3}	0.0	0.0	6.56×10^{2}
Americium-242m	7.86×10^{-3}	0.0	4.55×10^{2}	6.58×10^{2}
Americium-243	6.42×10^{-3}	1.13×10^{1}	1.29×10^{3}	6.10×10^{2}
Barium-137m	4.76×10^{6}	2.80×10^{7}	2.18×10^{8}	4.80×10^{6}
Carbon-14	1.29×10^{-2}	0.0	0.0	0.0
Cadmium-113m	0.0	7.79×10^{3}	8.96×10^{-8}	0.0
Cerium-144	0.0	0.0	6.30×10^{3}	0.0
Californium-249	0.0	0.0	1.25×10^{1}	0.0
Californium-251	0.0	0.0	2.87×10^{1}	0.0
Curium-242	7.86×10^{-3}	0.0	0.0	5.43×10^{2}
Curium-243	3.99×10^{-4}	8.28	1.45×10^{3}	0.0
Curium-244	1.24×10^{-2}	1.57×10^{2}	6.51×10^{6}	6.15×10^{3}
Curium-245	1.71×10^{-6}	0.0	5.22×10^{2}	0.0
Curium-246	4.02×10^{-8}	0.0	1.52×10^{2}	0.0
Curium-247	1.43×10^{-14}	0.0	5.99×10^{-3}	0.0
Curium-248	4.32×10^{-15}	0.0	0.0	0.0
Cobalt-60	3.98×10^{2}	1.87×10^{3}	2.50×10^{6}	0.0
Cesium-134	6.75×10^{1}	6.71×10^{2}	8.40×10^{5}	0.0
Cesium-135	7.53×10^{1}	0.0	9.17×10^{2}	1.93×10^{2}
Cesium-137	4.90×10^{6}	2.80×10^{7}	2.33×10^{8}	5.08×10^{6}
Europium-152	0.0	7.74×10^{2}	0.0	0.0
Europium-154	2.08×10^{4}	5.03×10^{4}	5.88×10^{6}	0.0
Europium-155	1.41×10^{2}	1.82×10^{3}	2.35×10^{3}	0.0
Hydrogen-3	6.70×10^{3}	0.0	0.0	0.0
Iodine-129	2.61	3.61×10^{1}	2.57×10^{-1}	0.0
Niobium-93m	6.42×10^{2}	2.00×10^{3}	5.15×10^{2}	2.03×10^{2}
Niobium-94	2.48×10^{-3}	0.0	0.0	0.0
Nickel-59	0.0	1.03×10^{3}	7.56×10^{2}	1.19×10^{2}
Nickel-63	0.0	9.06×10^{4}	4.94×10^{4}	9.64×10^{3}
Neptunium-237	2.85	1.06×10^{2}	1.19×10^{2}	3.55×10^{1}
Neptunium-238	0.0	0.0	0.0	2.97
Neptunium-239	0.0	0.0	0.0	6.10×10^{2}
Protactinium-231	0.0	2.05×10^{2}	0.0	4.91×10^{1}
Palladium-107	0.0	0.0	4.52	0.0
Promethium-147	9.15×10^{3}	0.0	1.70×10^{7}	0.0
Praseodymium-144	0.0	0.0	6.30×10^{3}	0.0
Plutonium-238	5.04×10^{4}	3.42×10^{3}	2.08×10^{7}	5.19×10^{3}
Plutonium-239	8.37×10^{2}	5.20×10^{4}	1.72×10^{5}	1.56×10^{3}
Plutonium-240	7.26×10^{2}	9.25×10^{3}	1.17×10^{5}	1.11×10^{3}
Plutonium-241	2.98×10^{4}	6.10×10^{4}	1.22×10^{7}	2.67×10^{4}
Plutonium-242	1.58	7.53×10^{-1}	3.89×10^{2}	3.04×10^{-3}
Radium-226	2.60×10^{-3}	6.78×10^{-2}	0.0	0.0

Table G-16. Radionuclide inventories (curies) for high-level radioactive waste (continued).

Radionuclide	Hanford Site[a]	Idaho National Laboratory[b]	Savannah River Site[c]	West Valley[d]
Radium-228	0.0	1.58×10^{1}	0.0	2.07
Ruthenium-106	0.0	1.51	1.65×10^{4}	0.0
Antimony-125	2.72×10^{2}	1.86×10^{3}	0.0	0.0
Antimony-126	0.0	0.0	0.0	7.59
Antimony-126m	0.0	0.0	0.0	5.42×10^{1}
Selenium-79	0.0	9.19×10^{1}	2.07×10^{2}	0.0
Samarium-151	0.0	2.46×10^{6}	4.27×10^{5}	5.08×10^{4}
Tin-126	4.12×10^{1}	4.36×10^{2}	1.08×10^{2}	5.42×10^{1}
Strontium-90	6.01×10^{6}	3.06×10^{7}	2.67×10^{8}	2.89×10^{6}
Technetium-99	1.58×10^{3}	2.24×10^{4}	5.46×10^{4}	8.90×10^{2}
Thorium-229	0.0	1.51	3.07×10^{-1}	7.51×10^{-3}
Thorium-230	1.72×10^{-1}	0.0	2.76×10^{-2}	3.28×10^{-4}
Thorium-232	4.48×10^{-8}	6.02	3.30	2.54
Thallium-208	0.0	0.0	0.0	6.65×10^{-1}
Uranium-232	2.75×10^{-3}	3.01×10^{1}	1.29	0.0
Uranium-233	2.76×10^{-4}	3.84×10^{2}	9.63×10^{1}	6.10
Uranium-234	4.28×10^{1}	1.66×10^{2}	2.84×10^{2}	2.65
Uranium-235	2.73×10^{-1}	6.78	2.10	2.15×10^{-5}
Uranium-236	7.12×10^{-1}	4.52	2.64×10^{1}	4.58×10^{-4}
Uranium-237	0.0	0.0	0.0	6.40×10^{-1}
Uranium-238	1.36×10^{-2}	1.50×10^{2}	1.81×10^{2}	0.0
Yttrium-90	6.01×10^{6}	3.06×10^{7}	2.67×10^{8}	2.89×10^{6}
Zirconium-93	0.0	3.62×10^{3}	6.58×10^{2}	2.03×10^{2}

a. The Hanford Site high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 5,325 canisters (DIRS 181377-BSC 2007, Section 7; DIRS 180471-BSC 2007, Table 8).
b. The Idaho National Laboratory high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 550 canisters (DIRS 181377-BSC 2007, Section 7; DIRS 180471-BSC 2007, Table 19).
c. The Savannah River Site high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 3,500 canisters (DIRS 181377-BSC 2007, Section 7; DIRS 180471-BSC 2007, Table 3).
d. The West Valley high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 300 canisters (DIRS 181377-BSC 2007, Section 7; DIRS 180471-BSC 2007, Table 17).

inventory and thereby the radiation dose. The following descriptions are for typical spent nuclear fuel for each group listed in Tables G-11 through G-14.

Group 1: Uranium Metal, Zirconium Alloy Clad, Low-Enriched Uranium. This group contains uranium metal fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.5 to 1.7 percent. The cladding is in fair to poor condition. This group of fuel comprises approximately 2,103 MTHM.

Group 2: Uranium Metal, Non-Zirconium Alloy Clad, Low-Enriched Uranium. This group contains uranium metal fuel compounds with no known zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.2 to 3.4 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 8 MTHM.

Group 3: Uranium-Zirconium. This group contains uranium-zirconium alloy fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.5 to 92.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.66 MTHM.

Group 4: Uranium-Molybdenum. This group contains uranium-molybdenum alloy fuel compounds with various types of cladding. The end-of-life effective enrichment ranges from 2.4 to 25.8 percent. If present, the cladding is in good to poor condition. This group of fuel comprises approximately 3.9 MTHM.

Group 5: Uranium Oxide, Intact Zirconium Alloy Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with intact zirconium alloy cladding. The end-of-life effective enrichment ranges from 23.1 to 92.5 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 1 MTHM.

Group 6: Uranium Oxide, Intact Zirconium Alloy Clad, Medium-Enriched Uranium. This group contains uranium oxide fuel compounds with intact zirconium alloy cladding. The end-of-life effective enrichment ranges from 5.0 to 6.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 1.9 MTHM.

Group 7: Uranium Oxide, Intact Zirconium Alloy Clad, Low-Enriched Uranium. This group contains uranium oxide fuel compounds with intact zirconium alloy cladding. The end-of-life effective enrichment ranges from 0.6 to 4.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 89.6 MTHM.

Group 8: Uranium Oxide, Intact Stainless-Steel/Hastelloy Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with intact stainless-steel or Hastelloy cladding. The end-of-life effective enrichment ranges from 91.0 to 93.2 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.19 MTHM.

Group 9: Uranium Oxide, Intact Stainless-Steel Clad, Medium-Enriched Uranium. This group contains uranium oxide fuel compounds with intact stainless-steel cladding. The end-of-life effective enrichment ranges from 5.5 to 20.0 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.69 MTHM.

Group 10: Uranium Oxide, Intact Stainless Steel Clad, Low-Enriched Uranium. This group contains uranium oxide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 0.2 to 1.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.9 MTHM.

Group 11: Uranium Oxide, Non-Intact or Declad Non-Aluminum Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with no known aluminum cladding. The end-of-life effective enrichment ranges from 21.0 to 93.3 percent. If present, the cladding is in poor condition. This group of fuel comprises approximately 0.82 MTHM.

Group 12: Uranium Oxide, Non-Intact or Declad Non-Aluminum Clad, Medium-Enriched Uranium. This group contains uranium oxide fuel compounds with no known aluminum cladding. The end-of-life effective enrichment ranges from 5.2 to 18.6 percent. If present, the cladding is in poor condition. This group of fuel comprises approximately 0.47 MTHM.

Group 13: Uranium Oxide, Non-Intact or Declad Non-Aluminum Clad, Low-Enriched Uranium. This group contains uranium oxide fuel compounds with no known aluminum cladding. The end-of-life effective enrichment ranges from 1.1 to 3.2 percent. If present, the cladding is in poor condition. This group of fuel comprises approximately 82.5 MTHM.

Group 14: Uranium Oxide, Aluminum Clad, Highly Enriched Uranium. This group contains uranium oxide fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 58.1 to 89.9 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 4.6 MTHM.

Group 15: Uranium Oxide, Aluminum Clad, Medium-Enriched Uranium and Low-Enriched Uranium. This group contains uranium oxide fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 8.9 to 20.0 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.29 MTHM.

Group 16: Uranium-Aluminum, Highly Enriched Uranium. This group contains uranium-aluminum alloy fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 21.9 to 93.3 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 7.5 MTHM.

Group 17: Uranium-Aluminum, Medium-Enriched Uranium. This group contains uranium-aluminum alloy fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 9.0 to 20.0 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 2.6 MTHM.

Group 18: Uranium-Silicide. This group contains uranium-silicide fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 5.2 to 22.0 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 7.2 MTHM.

Group 19: Thorium/Uranium Carbide, TRISO or BISO-Coated Particles in Graphite. This group contains thorium/uranium carbide fuel compounds with TRISO (tristructural isotopic)- or BISO (bistructural isotopic)-coated particles. TRISO-coated particles consist of an isotropic pyrocarbon outer layer, a silicon carbide layer, an isotropic carbon layer, and a porous carbon buffer inner layer. BISO-coated particles consist of an isotropic pyrocarbon outer layer and a low density porous carbon buffer inner layer. The end-of-life effective enrichment ranges from 71.4 to 84.4 percent. The coating is in good condition. This group of fuel comprises approximately 24.7 MTHM.

Group 20: Thorium/Uranium Carbide, Mono-Pyrolytic Carbon-Coated Particles in Graphite. This group contains thorium/uranium carbide fuel compounds with mono-pyrolytic carbon-coated particles. The end-of-life effective enrichment ranges from 80.6 to 93.2 percent. The coating is in poor condition. This group of fuel comprises approximately 1.6 MTHM.

Group 21: Plutonium/Uranium Carbide, Nongraphite Clad, Not Sodium Bonded. This group contains plutonium/uranium carbide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 1.0 to 67.3 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 0.08 MTHM.

Group 22: Mixed Oxide, Zirconium Alloy Clad. This group contains plutonium/uranium oxide fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 1.3 to 21.3 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 1.6 MTHM.

Group 23: Mixed Oxide, Stainless-Steel Clad. This group contains plutonium/uranium and plutonium oxide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 2.1 to 87.4 percent. The cladding is in good poor condition. This group of fuel comprises approximately 10.7 MTHM.

Group 24: Mixed Oxide, Non-Stainless Steel/Non-Zirconium Alloy Clad. This group contains plutonium/uranium oxide fuel compounds with no known stainless-steel or zirconium alloy cladding. The end-of-life effective enrichment ranges from 5.0 to 54.3 percent. The cladding is in poor to nonintact condition. This group of fuel comprises approximately 0.11 MTHM.

Group 25: Thorium/Uranium Oxide, Zirconium Alloy Clad. This group contains thorium/uranium oxide fuel compounds with zirconium alloy cladding. The end-of-life effective enrichment ranges from 10.1 to 98.4 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 42.6 MTHM.

Group 26: Thorium/Uranium Oxide, Stainless-Steel Clad. This group contains thorium/uranium oxide fuel compounds with stainless-steel cladding. The end-of-life effective enrichment ranges from 7.6 to 97.8 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 7.6 MTHM.

Group 27: Uranium-Zirconium Hydride, Stainless-Steel/Incoloy Clad, Highly Enriched Uranium. This group contains uranium zirconium hydride fuel compounds with stainless-steel or Incoloy cladding. The end-of-life effective enrichment ranges from 42.5 to 93.2 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.16 MTHM.

Group 28: Uranium-Zirconium Hydride, Stainless-Steel/Incoloy Clad, Medium-Enriched Uranium. This group contains uranium zirconium hydride fuel compounds with stainless-steel or Incoloy cladding. The end-of-life effective enrichment ranges from 11.9 to 20.0 percent. The cladding is in good to poor condition. This group of fuel comprises approximately 1.4 MTHM.

Group 29: Uranium-Zirconium Hydride, Aluminum Clad, Medium-Enriched Uranium. This group contains uranium zirconium hydride fuel compounds with aluminum cladding. The end-of-life effective enrichment ranges from 16.8 to 20.0 percent. The cladding is in good condition. This group of fuel comprises approximately 0.35 MTHM.

Group 30: Uranium-Zirconium Hydride, Declad. This group contains uranium zirconium hydride fuel compounds that have been declad. The end-of-life effective enrichment is about 89.7 percent. This group of fuel comprises approximately 0.03 MTHM.

Group 31: Metallic Sodium Bonded. This group contains a wide variety of spent nuclear fuel that has the common attribute of containing metallic sodium bonding between the fuel matrix and the cladding. The end-of-life effective enrichment ranges from 0.1 to 93.2 percent. If present, the cladding is in good to poor condition. This group of fuel comprises approximately 59.9 MTHM. This spent nuclear fuel will be treated and disposed of as high-level radioactive waste.

Group 32: Naval Fuel. Naval nuclear fuel is highly robust and designed to operate in a high-temperature, high-pressure environment for many years. This fuel is highly enriched (93 to 97 percent) in uranium-235. In addition, to ensure that the design will be capable of withstanding battle shock loads, the naval fuel material is surrounded by large amounts of zirconium alloy. This group of fuel comprises approximately 65 MTHM.

Group 33: Canyon Stabilization. This spent nuclear fuel is being treated and will be disposed of as high-level radioactive waste.

Group 34: Miscellaneous. This group contains spent nuclear fuel that does not fit into other groups. The spent nuclear fuel in this group was generated from numerous reactors of different types. The end-of-life effective enrichment ranges from 14.6 to 90.0 percent. If present, the cladding is in good to poor condition. This group of fuel comprises of approximately 0.44 MTHM.

The DOE spent nuclear fuel radionuclide inventories are for the amount of spent nuclear fuel that DOE would ship in rail casks. The DOE spent nuclear fuel radionuclide inventory is based on 752 canisters from the Hanford Site, 1,603 canisters from the Idaho National Laboratory, and 400 canisters from the Savannah River Site. These inventories were compiled from data in DIRS 169354-DOE 2004, Volume II, Appendix C. For naval spent nuclear fuel, the radionuclide inventory is for 400 casks containing 400 canisters. The single cask naval spent fuel inventory was compiled from DIRS 155857-McKenzie 2001, Table 3. Tables G-11 through G-14 list the radionuclide inventories for DOE spent nuclear fuel.

For commercial spent nuclear fuel, the radionuclide inventories are for the amount of spent nuclear fuel that DOE would ship in rail and truck casks. For pressurized-water-reactor spent nuclear fuel, DOE would ship an estimated 93,671 spent nuclear fuel assemblies in rail and truck casks (DIRS 181377-BSC 2007, Section 7). For boiling-water-reactor spent nuclear fuel, the Department would ship 128,105 spent nuclear fuel assemblies in rail and truck casks (DIRS 181377-BSC 2007, Section 7). This analysis assumed that all shipping casks would be full and all trains would have a full complement of casks. This increases the number of spent nuclear fuel assemblies to 94,817 for pressurized-water-reactor spent nuclear fuel and 129,721 for boiling-water-reactor spent nuclear fuel. The representative pressurized-water-reactor assembly would have a burnup of 60,000 megawatt-days per MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 169061-BSC 2004, all). The representative boiling-water-reactor assembly would have a burnup of 50,000 megawatt-days per MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 164364-BSC 2003, all). Table G-15 lists the radionuclide inventory for commercial spent nuclear fuel.

The high-level radioactive waste radionuclide inventory is based on 5,316 canisters from Hanford Site, 528 canisters from Idaho National Laboratory, 3,490 canisters from Savannah River Site, and 277 canisters from West Valley (DIRS 181377-BSC 2007, Section 7). This analysis assumed that all shipping casks that contained high-level radioactive waste would be full and all trains would have a full complement of casks. This increases the amount of high-level radioactive waste to 5,325 canisters for

Hanford Site, 550 canisters for Idaho National Laboratory, 3,500 canisters for Savannah River Site, and 300 canisters from West Valley. Table G-16 lists the radionuclide inventory for high-level radioactive waste.

G.6 Incident-Free Transportation

The impacts from incident-free transportation can be related to either the cargo being carried or to the vehicle that carries the cargo. Incident-free impacts that are related to the cargo are known as radiological impacts. Incident-free impacts that are related to the vehicle are nonradiological in nature and are known as vehicle emission impacts.

G.6.1 RADIOLOGICAL IMPACTS

Radiation doses during normal, incident-free transportation of radioactive materials result from exposure of workers and the public to the external radiation field that surrounds the shipping containers. The radiation dose is a function of the number of people exposed, their proximity to the containers, their length of time of exposure, and the intensity of the radiation field.

In most cases, rail casks would be shipped to the repository using dedicated trains. A dedicated train would consist only of equipment and lading associated with the transportation of spent nuclear fuel and high-level radioactive waste; that is, the train would consist only of necessary motive power, buffer cars, and cask cars, together with a car for escort personnel. Such a train would not transport other rail rolling stock, other revenue, or company freight. For shipments of commercial spent nuclear fuel, there would be three casks that contained spent nuclear fuel per train. For shipments of DOE spent nuclear fuel and high-level radioactive waste, there would be five casks per train. Other numbers of casks per train could be possible for shipments of commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste. In both cases, two buffer railcars, two locomotives, and one escort railcar would be in the train. Escorts would be present in all areas (rural, suburban, and urban) for all rail shipments.

Truck casks would be shipped to the repository on overweight trucks. Escorts would be present in all areas (rural, suburban, and urban) for all truck shipments.

DOE determined radiological impacts for members of the public and workers during normal, incident-free transportation of the casks. For members of the public, the Department estimated radiation doses for:

- People within 800 meters (0.5 mile) of the transportation route. The doses to these people are referred to as off-link radiation doses.

- People in vehicles sharing the transportation route. The doses to these people are referred to as on-link radiation doses.

- People exposed at stops that occur en route to the repository. For truck transportation, these would include stops for refueling, food, and rest, and for brief inspections at regular intervals. For rail transportation, stops would occur in rail yards at the beginning of the trip, at the Staging Yard at the end of the trip, and along the route to change crews and equipment. Stops would also include the intermodal transfers of rail casks for shipments from generator sites without direct rail access.

- Workers such as truck drivers, escorts, inspectors, and workers at rail yards or at the Staging Yard at the end of the trip. Engineers and conductors would be in the train locomotives at least 46 meters (150 feet) from the closest rail cask, shielded from radiation exposure by the locomotives; therefore, there would be no radiation doses for these workers en route to the repository. Workers would also be exposed during Commercial Vehicle Safety Alliance truck inspections at the beginning and end of a shipment and during intermodal transfers of rail casks for shipments from generator sites without direct rail access.

G.6.1.1 Collective Radiation Dose Scenarios

Radiation doses received by a population of workers or members of the public are referred to as collective radiation doses. DOE estimated collective radiation doses based on unit risk factors. Unit risk factors provide an estimate of the radiation doses from transport of one shipment or container of radioactive material over a unit distance of travel in a given population density zone.

Unit risk factors can provide an estimate of the radiation dose from one container or shipment being stopped at a location such as a rail yard or the radiation dose from one container or shipment passing a train stopped at a siding. DOE used five types of unit risk factors to estimate collective incident-free radiation doses:

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks, the population density in each population zone, and the distance in each population zone.

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks and the distance in each population zone.

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks and the population density around locations such as a rail yard.

- Unit risk factors to estimate incident-free radiation doses that depended on the number of trains (that is, shipments) and the distance in each population zone.

- Unit risk factors to estimate incident-free radiation doses that depended on the number of casks.

The Yucca Mountain FEIS (DIRS 155970-DOE 2002, p. J-40) contains a more detailed explanation of how DOE used unit risk factors to estimate radiation doses. As in the FEIS (DIRS 155970-DOE 2002, Section J.1.3.2), DOE estimated the unit risk factors using the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) and the RISKIND computer program (DIRS 101483-Yuan et al. 1995, all). Both RADTRAN and RISKIND have been verified and validated for estimating incident-free radiation doses during transportation of radioactive material (DIRS 101845-Maheras and Pippen 1995, all; DIRS 177031-Osborn et al. 2005, all; DIRS 102060-Biwer et al. 1997, all).

The incident-free unit risk factors used in the analysis in this Repository SEIS are similar to those in the Yucca Mountain FEIS (DIRS 157144-Jason Technologies 2001, Tables 4-20 and 4-21) with the following changes:

- The dedicated train exposure factors are used to estimate worker and public exposures during stops at rail yards. One stop would occur at the rail yard closest to the generator site and another at the Staging Yard in Nevada. A stop time of 2 hours was used for these stops. Two-hour stops would also occur every 277 kilometers (170 miles). For shipments using regular freight trains, a 30-hour stop was used to estimate worker and public exposures.

- Escorts would be present in the escort car from the time the train was assembled at the generator site until it reached its final destination at the repository.

- For generator sites without direct rail access, four escort cars would accompany the heavy-haul truck carrying the rail cask. At the point where the rail cask was moved from the heavy-haul truck to the railcar, assembly of the dedicated train would take 30 hours. The escorts would be present for this 30-hour period.

- A train containing commercial spent nuclear fuel would contain three casks. A train containing DOE spent nuclear fuel and high-level radioactive waste would contain five casks. The escorts would be exposed only to radiation from by the cask closest to the escort car. The shielding of this car would effectively shield the escorts from the other casks in the train.

- Unit risk factors were estimated for workers at the Maintenance-of-Way Facility, workers at sidings, and noninvolved workers at the Staging Yard; the Yucca Mountain FEIS did not address these facilities and activities. These unit risk factors are discussed in Appendix K of the Rail Alignment EIS.

As in the Yucca Mountain FEIS, DOE set the external dose rates for the truck and rail casks at their regulatory maximum, 10 millirem per hour at 2 meters (6.6 feet) from the truck trailer or railcar.

G.6.1.2 Maximally Exposed Individual Dose Scenarios

Maximally exposed individuals are hypothetical workers and members of the public who would receive the highest radiation doses. The scenarios DOE used to estimate the radiation doses are similar to the scenarios in the Final Yucca Mountain EIS (DIRS 155970-DOE 2002, Section J.1.3.2.2), and were evaluated on the national level and on the Nevada level. National scenarios incorporate conditions such as speeds, distances, and exposure times that would be representative of exposures across the United States Nevada scenarios incorporate site-specific conditions for exposures in Nevada.

G.6.1.2.1 *National Scenarios*

For workers, DOE evaluated the following scenarios:

- An escort 27 meters (90 feet) from the rail cask. This person would be exposed for 2,000 hours per year. The 27-meter distance includes the length of the buffer railcar between the last rail cask car and the escort car.

- An inspector 1 meter (3.3 feet) from the rail or truck cask for 1 hour per cask. This person would be exposed for 2,000 hours per year (DIRS 155970-DOE 2002, p. J-42).

- A truck driver who would drive shipments that contained loaded casks for 1,000 hours per year and unload casks for 1,000 hours per year.

- A rail yard crew member 10 meters (33 feet) from the rail cask for 2 hours per cask. This person would be exposed for 2,000 hours per year (DIRS 155970-DOE 2002, p. J-42).

For members of the public, DOE evaluated the following scenarios:

- Typically, there is an 18-meter (60-foot) buffer zone around rail lines that is railroad property, within which people cannot build homes. Therefore, DOE estimated the radiation dose to a resident living 18 meters from a rail line. This individual was assumed to be exposed to all loaded rail casks as they passed by en route to the repository.

- A resident 200 meters (660 feet) from a rail yard. This person would be exposed for 2 hours per cask (DIRS 155970-DOE 2002, p. J-42).

- A person stuck in a traffic jam next to the cask for 1 hour. The person would be 1.2 meters (4 feet) from the cask (DIRS 155970-DOE 2002, p. J-42).

- A resident 30 meters (100 feet) from a road or highway. This individual would exposed to all loaded truck casks as they passed by en route to the repository (DIRS 155970-DOE 2002, p. J-42).

- A person at a service station. This person would be exposed for 49 minutes to each truck cask at a distance of 16 meters (52 feet) (DIRS 155970-DOE 2002, p. J-42).

G.6.1.2.2 *Nevada Scenarios*

For workers, DOE evaluated the following scenarios:

- An escort 27 meters (90 feet) from the rail cask. This person would be exposed for 2,000 hours per year. The 27-meter distance includes the length of the buffer railcar between the last rail cask car and the escort car.

- An inspector 1 meter (3.3 feet) from the rail or truck cask for 1 hour per cask. This person would be exposed for 2,000 hours per year.

- A rail yard crew member 10 meters (33 feet) from the rail cask for 2 hours per cask. This person would be exposed for 2,000 hours per year.

For workers, two scenarios that were not addressed in the Yucca Mountain FEIS have been added to the analysis for this Repository SEIS:

- In the first scenario, a worker at the Maintenance-of-Way Facility would be exposed to a loaded cask train traveling 50 kilometers (31 miles) per hour as it passed the facility en route to the repository. This worker would be 60 meters (200 feet) from the cask as it passed.

- In the second scenario, a worker at a siding would be exposed to a loaded rail cask train traveling 50 kilometers (31 miles) per hour as it passed the siding en route to the repository. This worker would be 7.62 meters (25 feet) from the rail cask as it passed.

A separate truck driver scenario was not evaluated in Nevada because the exposure of the driver was based on travel from generator sites to the repository, and there would be no drivers who drove solely in Nevada.

For members of the public, the following scenarios were evaluated:

- Typically, there is an 18-meter (60-foot) buffer zone around rail lines that is railroad property and within which people cannot build homes. Therefore, DOE estimated the radiation dose to a resident living 18 meters from a rail line. This individual was assumed to be exposed to all loaded rail casks as they passed by en route to the repository.

- In some cases, individuals could have access to locations that are closer than 18 meters (60 feet) from a rail line. For example, Nevada Agency for Nuclear Projects (DIRS 158452 Nevada Agency for Nuclear Projects 2002, p. 123) states that in the Las Vegas area, individuals could be 15, 20, 30, 35, 40, 100, and 160 meters (49, 66, 98, 115, 131, 328, and 525 feet) from the rail line. In the area of the Reno Trench, an individual could be as close as 5 meters (16 feet) from the rail line. Therefore, radiation doses were estimated for individuals at these distances from the rail line. These locations were not permanently occupied by residents. However, to provide a conservative estimate of potential impacts, they were assumed to be exposed to all loaded casks that passed through Las Vegas or Reno en route to the repository.

- In Nevada, Interstate Highway 15, the Las Vegas beltway, and U.S. Highway 95 would be used for truck shipments. There are typically buffer zones along Interstate highways and beltways so people cannot build homes much closer then about 30 meters (100 feet) from the road. However, Highway 95 passes through Indian Springs on the way to the repository. In Indian Springs, an individual could reside as close as 24 meters (80 feet) from the highway. Therefore, the radiation dose was estimated for an individual who resided at this location and who was exposed to all loaded truck casks as they passed by en route to the repository.

- A person stuck in a traffic jam next to the cask for 1 hour. The person would be 1.2 meters (4 feet) from the cask.

- A person at a service station. This person would be exposed for 49 minutes to each truck cask at a distance of 16 meters (52 feet) (DIRS 155970-DOE 2002, p. J-42).

- A resident living near the staging yard would be exposed to all loaded casks at the yard for a duration of 2 hours per cask. Table G-17 lists the distances from the staging yard for these residents, which were based on site-specific data around each yard.

G.6.2 VEHICLE EMISSION IMPACTS

The analysis estimated incident-free impacts from vehicle emissions using unit risk factors that account for fatalities associated with emissions of exhaust and fugitive dust in urban, suburban, and rural areas by

Table G-17. Distances to members of the public around staging yards.

Staging yard location	Distance (meters)	Type of location
Caliente-Indian Cove	1,600	Residence
Caliente-Upland	400	Residence
Eccles-North	1,500	Residence
Mina-Hawthorne	660	Business

Note: Conversion factors are on the inside back cover of this Repository SEIS.

transportation vehicles, including escort vehicles. Because the impacts would occur equally for trucks and railcars transporting loaded or unloaded shipping casks, the analysis used round-trip distances. Because escorts were present in all areas, escort vehicle emission impacts were also estimated based on round trips.

For trucks, the vehicle emission unit risk factor was 1.5×10^{-11} fatalities per kilometer per person per square kilometer (DIRS 157144-Jason Technologies 2001, p. 98). For escort vehicles, the vehicle emission unit risk factor was 9.4×10^{-12} fatalities per kilometer per person per square kilometer (DIRS 157144-Jason Technologies 2001, p. 99). For railcars, the vehicle emission unit risk factor was 2.6×10^{-11} fatalities per kilometer per person per square kilometer (DIRS 157144-Jason Technologies 2001, p. 99).

G.7 Transportation Accident Risks

Transportation accident risks can be related either to the cargo being carried or to the vehicle that carries the cargo. Transportation accident risks that are related to the cargo are known as radiological accident risks. Transportation accident risks that are related to the vehicle are nonradiological in nature and are known as transportation accident fatalities.

G.7.1 TRANSPORTATION RADIOLOGICAL ACCIDENT RISKS

The radiological dose risks from transporting spent nuclear fuel and high-level radioactive waste would result from: (1) accidents in which there was no breach of the containment provided by the transportation cask, but there was loss of shielding because of lead shield displacement, (2) accidents in which there was no breach of the containment and no loss of shielding, and (3) accidents that released and dispersed radioactive material from the transportation cask. In this Repository SEIS, the risk to the general public from the radiological consequences of transportation accidents is called dose risk. Dose risk is the sum of the products of the probabilities (dimensionless) and the consequences (in person-rem) of all potential transportation accidents. The probability of a single accident is usually determined by historical information on accidents of a similar type and severity. The consequences are estimated by analysis of the quantity of radionuclides likely to be released, potential exposure pathways, potentially affected population, likely weather conditions, and other information.

Potential accidents range from accidents with higher probabilities and lower consequences to accidents with lower probabilities and higher consequences. The analysis used the following information to determine the risks of accidents:

- The number of shipments;

- The distances and population densities along the transportation routes in rural, suburban, and urban areas;
- The kind and amount of radioactive material that would be transported;
- Transportation accident rates;
- Conditional probabilities of release and the fraction of cask contents that could be released in accidents;
- Conditional probabilities of amounts of lead shielding displacement that could occur during accidents, and the resulting radiation dose rates; and
- Exposure scenarios including inhalation, ingestion, groundshine, resuspension, and immersion pathways, state-specific agricultural factors, and neutral (or average) atmospheric dispersion factors.

As in the incident-free transportation analysis, DOE used the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) to estimate unit risk factors for accidents that involved loss of shielding or when the shielding was undamaged. RADTRAN5 was also used to estimate unit risk factors for accidents that involved the release of radioactive material from the cask, for each radionuclide of concern in spent nuclear fuel and high-level radioactive waste. RADTRAN has been verified and validated for estimating the accident risks from transport of radioactive material (DIRS 101845-Maheras and Pippen 1995, all; DIRS 177031-Osborn et al. 2005, all). The unit risk factors were combined with radionuclide inventories, number of shipments, accident rates, conditional probabilities of release, release fractions, distance, and population densities to determine the dose risk for populations within 80 kilometers (50 miles) of the rail alignment.

The methods and data DOE used to estimate the dose risks were the same as those in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Section J.1.4.2) with the following exceptions:

- The distances and population densities have been updated,
- The number of rail casks to be shipped has been updated,
- Track Class-specific rail accident rates were used in the analysis,
- Truck accident rates have been updated,
- The radionuclide inventories have been updated through additional data collection and analysis,
- Updated radiation dosimetry has been used to estimate unit risk factors and radiation doses, and
- Updated health risk conversion factors have been used to estimate the number of latent cancer fatalities.

TRACK CLASS

The Federal Railroad Administration's Track Safety Standards, at 49 CFR Part 213, establish track structure and track geometry requirements for nine separate classes of track (Sections 213.9 and 213.307) with designated maximum speeds for each class. Railroads indicate the class to which each track belongs. Once the designation is made, the railroads are held responsible for maintaining each track to specified tolerances for its designated class. A railroad becomes liable for civil penalties if it fails to maintain a track to proper standards, or if it operates trains at speeds in excess of the limits of the designated class.

- The lowest class is referred to as excepted track. Only freight trains are allowed to operate on this type of track, and they may run at speeds up to 10 miles per hour.
- Class 1 track is the lowest class allowing the operation of passenger trains. Freight train speeds are still limited to 10 miles per hour, and passenger trains are restricted to 15 miles per hour.
- Class 2 track limits freight trains to 25 miles per hour and passenger trains to 30 miles per hour.
- Class 3 track limits freight trains to 40 miles per hour and passenger trains to 60 miles per hour.
- Class 4 track limits freight trains to 60 miles per hour and passenger trains to 80 miles per hour. Most through lines, especially owned by the major Class 1 railroads (BNSF, CSX, Norfolk Southern, and Union Pacific), are Class 4 track.
- Class 5 track limits freight trains to 80 miles per hour and passenger trains to 90 miles per hour. The most significant portion of Class 5 track is in the western part of the Union Pacific mainlines, but the top speed on these lines is limited to 70 miles per hour.

In the United States, the regulations for Track Classes 6 through 9 are designed for passenger trains. Any freight cars moved at passenger speeds must meet the dynamic performance standards of passenger equipment. The only such track is Amtrak passenger lines in the Northeast Corridor.

- Class 6 limits freight trains and passenger trains to 110 miles per hour.
- Class 7 limits freight trains and passenger trains to 125 miles per hour. Most of Amtrak's Northeast Corridor is Class 7 track.
- Class 8 limits freight trains and passenger trains to 160 miles per hour. A few small lengths of Amtrak's Northeast Corridor is Class 8 track.
- Class 9 limits freight trains and passenger trains to 200 miles per hour. There is currently no Class 9 track in the United States.

G.7.1.1 Transportation Accident and Fatality Rates

In the Yucca Mountain FEIS, DOE used rail accident rates from the *State-Level Accident Rates of Surface Freight Transportation: A Reexamination* (DIRS 103455-Saricks and Tompkins 1999, all) to estimate radiological transportation risks. These rates were in terms of accidents per railcar kilometers and were based on 68-railcar trains. Because DOE has adopted a policy of using dedicated trains that would contain 8 to 10 cars on average for shipments of commercial spent nuclear fuel and for most DOE spent nuclear fuel and high-level radioactive waste in this Repository SEIS, a combination of rail accident rates based on both train kilometers and railcar kilometers was used to estimate accident risks (Table G-18). These rates were for Track Class 3 and include derailments and collisions (DIRS 180220-Bendixen and Facanha 2007, all). DOE updated rail fatality rates to reflect data from 2000 to 2004 (DIRS 178016-DOT 2005, all). These fatality rates were in terms of fatalities per railcar kilometer.

Table G-18. Track Class 3 rail accident rates.

Train-based accident rate (accidents per train kilometer)	Railcar-based accident rate (accidents per railcar kilometer)
7.5×10^{-7}	1.7×10^{-8}

Source: DIRS 180220-Bendixen and Facanha 2007, all.
Note: Conversion factors are on the inside back cover of this Repository SEIS.

In the Yucca Mountain FEIS, DOE used state-specific accident and fatality rate data for 1994 to 1996 (DIRS 103455-Saricks and Tompkins 1999, all) to estimate transportation impacts. For trucks, the Department obtained accident and fatality rate data it used in the FEIS from the U.S. Department of Transportation, Federal Motor Carrier Safety Administration, Motor Carrier Management Information System. Since completion of the FEIS, the Federal Motor Carrier Safety Administration has evaluated the data in the Information System. For 1994 through 1996, it found that accidents were underreported by about 39 percent and fatalities were underreported by about 36 percent (DIRS 181755-UMTRI 2003, Table 1, p. 4, and Table 2, p. 6). Therefore, in this Repository SEIS, DOE increased the state-specific truck accident and fatality rates from Saricks and Tompkins by factors of 1.64 and 1.57, respectively, to account for the underreporting.

G.7.1.2 Conditional Probabilities and Release Fractions

In this Repository SEIS, DOE spent nuclear fuel is organized into 34 groups based on the fuel compound, fuel matrix, fuel enrichment, fuel cladding material, and fuel cladding condition. Commercial spent nuclear fuel is organized into two groups, pressurized-water reactor and boiling-water reactor spent nuclear fuel. High-level radioactive waste is organized into four groups: that from Idaho National Laboratory, Hanford Site, Savannah River Site, and West Valley. These groups were assigned to a set of 10 conditional probabilities and release fractions known as release fraction groups based on the characteristics and behavior of the spent nuclear fuel or high-level radioactive waste (DIRS 157144-Jason Technologies 2001, Tables 5-24 to 5-27, 5-33, 5-35, 5-39, 5-41, 5-43, 5-45, 5-46, and 5-48). Release fractions were specified for inert gases, volatile constituents such as cesium and ruthenium, particulates, and activation products such as cobalt-60 that were deposited on the exterior surfaces of the spent nuclear fuel (also known as crud).

For loss-of-shielding accidents, the Yucca Mountain FEIS lists unit risk factors for six severity categories (DIRS 155970-DOE 2002, p. J-54, Table J-19). These unit risk factors are used in this analysis.

G.7.1.3 Atmospheric Conditions

Atmospheric conditions would affect the dispersion of radionuclides that could be released from an accident. Because it is not possible to forecast the atmospheric conditions that might exist during an accident, DOE selected neutral weather conditions (Pasquill Stability Class D) for the transportation risk assessments for the Yucca Mountain FEIS and for this Repository SEIS. Neutral weather conditions are typified by moderate wind speeds, vertical mixing in the atmosphere, and good dispersion of atmospheric contaminants. On the basis of observations from National Weather Service surface meteorological stations at 177 locations in the United States, on an annual average, neutral conditions (Pasquill Class C and D) occur 11 percent and 47 percent of the time, respectively. Stable conditions (Pasquill Class E and F) occur 12 percent and 21 percent of the time, respectively. Unstable conditions (Pasquill Class A and B) occur 1 percent and 7 percent of the time, respectively (DIRS 104800-CRWMS M&O 1999, p. 40).

G.7.1.4 Population Density Zones

DOE used three population density zones (urban, rural, and suburban) for the transportation risk assessment. Urban areas were defined as areas with a population density greater than 3,326 people per square kilometer. Rural areas were defined as areas with a population density less than 139 people per square kilometer. Suburban areas were areas with a population density between 139 and 3,326 people per square kilometer. The actual population densities were based on 2000 Census data. In Las Vegas, the population density was modified to include casino guests and casino workers, based on data from the Nevada Agency for Nuclear Projects (DIRS 158452-Nevada Agency for Nuclear Projects 2002, Table 3.8.12). The population densities and radiological impacts were escalated to 2067 using the escalation factors in Table G-6.

G.7.1.5 Exposure Pathways

DOE estimated radiological doses for an individual near the scene of the accident and for populations within 80 kilometers (50 miles) of the accident. Dose calculations considered a variety of exposure pathways, including inhalation and direct exposure (immersion or cloudshine) from the passing cloud, ingestion of contaminated food, direct exposure (groundshine) from radioactivity deposited on the ground, and inhalation of resuspended radioactive particles from the ground (resuspension).

G.7.1.6 Unit Risk Factors and Radiation Dosimetry

As discussed in Section G.7.1, DOE estimated the radiation doses from transportation accidents using unit risk factors. Unit risk factors were estimated using the RADTRAN 5 computer program (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser et al. 2000, all) for five pathways: (1) ingestion, (2) inhalation, (3) immersion, (4) resuspension, and (5) groundshine. For transportation accidents, unit risk factors provide estimates of:

- The radiation dose to an average person in a surrounding unit area (for example, a population density of one person per square kilometer) that could result if 1 curie of a specified radionuclide were released.

- The dose to a general population from ingestion of contaminated food from the accidental release of one curie of a specified radionuclide. The unit risk factor includes the assumption that all contaminated food is consumed.

- For transportation accidents in which a portion of a cask's radiation shield was damaged or lost (loss-of-shielding accidents), and for cases in which the cask’s shield could remain intact, unit risk factors provide estimates of the resulting radiation dose to a person in a surrounding unit area after an accident.

DOE used the inhalation and ingestion dose coefficients from DIRS 172935-ICRP (2001, all) and the groundshine and immersion dose coefficients from DIRS 175544-EPA (2002, all) to estimate the unit risk factors. These dose coefficients are based on the recommendations by International Commission on Radiological Protection Publication 60 (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from International Commission on Radiological Protection Publication 72 (DIRS 152446-ICRP 1996, all). For each radionuclide, the dose coefficients DOE used to estimate the unit risk factors, which are listed in DIRS 176975-BMI (2006, Table 5), include radioactive progeny (DIRS 176975-BMI 2006, Table 2). This table also lists the lung absorption type and the value for the fractional absorption to blood from the small intestine (f_1) for each radionuclide.

G.8 Severe Transportation Accidents

In addition to analyzing the radiological and nonradiological risks of transporting spent nuclear fuel and high-level radioactive waste, DOE assessed the consequences of severe transportation accidents; such accidents with a frequency of about 1×10^{-7} per year are known as maximum reasonably foreseeable transportation accidents. According to DOE guidance, accidents that have a frequency of less then 1×10^{-7} rarely need to be examined (DIRS 172283-DOE 2002, p. 9).

The analysis was based on the 20 rail accident severity categories identified in Sprung et al. (DIRS 152476-Sprung et al. 2000, pp. 7-73 and 7-76). The following list describes these severity categories:

- Case 20: Case 20 is a long-duration (many hours), high-temperature fire that would engulf a cask.

- Cases 19, 18, 17, and 16: Case 19 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard object such as a train locomotive severe enough to cause failure of cask seals and puncture through the cask's shield wall. The impact would be followed by a very-long-duration, high-temperature engulfing fire. Cases 18, 17, and 16 are accidents that would also involve very-long-duration fires, failures of cask seals, and puncture of cask walls. However, these accidents would be progressively less severe in terms of impact speeds. The impact speeds range from 145 to 190 kilometers (90 to 120 miles) per hour for Case 18, 97 to 145 kilometers (60 to 90 miles) per hour for Case 17, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 16.

- Cases 15, 12, 9, and 6: Case 15 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by a long-duration, high-temperature engulfing fire. Cases 12, 9, and 6 are also accidents that would involve long-duration fires and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds ranging from 145 to 190 kilometers (90 to 120 miles) per hour for Case 12, 97 to 145 kilometers (60 to 90 miles) per hour for Case 9, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 6.

- Cases 14, 11, 8, and 5: Case 14 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by a high-temperature engulfing fire that burned for hours. Cases 11, 8, and 5 are also accidents that would involve fires that would burn for hours and failures of cask seals. However, these accidents would be progressively less severe in terms of impact speeds ranging from 145 to 190 kilometers (90 to 120 miles) per hour for Case 11, 97 to 145 kilometers (60 to 90 miles) per hour for Case 8, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 5.

- Cases 13, 10, 7, and 4: Case 13 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface such as granite severe enough to cause failure of cask seals. The impact would be followed by an engulfing fire lasting more than 0.5 hour to a few hours. Cases 10, 7, and 4 are accidents that would involve long-duration fires and failures of cask seals. However, these accidents are progressively less severe in terms of impact speeds ranging from 145 to 190 kilometers

(90 to 120 miles) per hour for Case 10, 97 to 145 kilometers (60 to 90 miles) per hour for Case 7, and 48 to 97 kilometers (30 to 60 miles) per hour for Case 4.

- Cases 3, 2, and 1: Case 3 is a high-speed [more than 190 kilometers (120 miles) per hour] impact into a hard surface such as granite severe enough to cause failure of cask seals with no fire. Cases 2 and 1 are also accidents that would not involve fire but would have progressively lower impact speeds, 145 to 190 kilometers (90 to 120 miles) per hour for Case 2 and 97 to 145 kilometers (60 to 90 miles) per hour for Case 1.

Each of the 20 accident cases above has an associated conditional probability of occurrence (DIRS 152746-Sprung et al. 2000, p. 7-76). These conditional probabilities were combined with the distances along the transportation routes presented in Section G.3, the shipment data presented in section G.4, and the accident rates discussed in Section G.7.1.1 to estimate the frequency of occurrence for each accident case. These frequencies are listed in Table G-19. Cases 1, 4, and 20 have frequencies greater than 1×10^{-7} per year. Based on the results presented in Table J-22 of the Yucca Mountain FEIS (DIRS 155970-DOE 2002), Case 20 is estimated to have the highest consequences of these 3 accident cases. Therefore, Case 20 is considered to be the maximum reasonably foreseeable transportation accident.

Table G-19. Annual frequencies for accident severity cases.

Accident severity case	Annual frequency (accidents per year)
1	8×10^{-7}
2	$5 \times 10^{-8} – 6 \times 10^{-8}$
3	$4 \times 10^{-10} – 5 \times 10^{-10}$
4	3×10^{-6}
5	8×10^{-8}
6	1×10^{-8}
7	7×10^{-9}
8	2×10^{-10}
9	$2 \times 10^{-11} – 3 \times 10^{-11}$
10	5×10^{-10}
11	1×10^{-11}
12	2×10^{-12}
13	4×10^{-12}
14	1×10^{-13}
15	1×10^{-14}
16	4×10^{-11}
17	$2 \times 10^{-14} – 3 \times 10^{-14}$
18	2×10^{-15}
19	1×10^{-17}
20	5×10^{-6}

Based on the analysis in the Yucca Mountain FEIS, accidents that would involve truck casks yielded lower consequences than accidents that would involve rail casks (DIRS 155970-DOE 2002, Tables J-22 and J-23). Therefore, DOE did not update severe accidents involving truck casks in this Repository SEIS.

DOE used the following assumptions to estimate the consequences of these accidents (DIRS 157144-Jason Technologies 2001, Section 5.3.3.3):

- A release height of the plume of 10 meters (33 feet) for fire- and impact-related accidents. In the case of an accident with a fire, a 10-meter release height with no plume rise from the buoyancy of the plume due to fire conditions would yield higher estimates of consequences than accounting for the buoyancy of the plume from the fire (DIRS 157144-Jason Technologies 2001, p. 176).

- A breathing rate for individuals of 10,400 cubic meters (367,000 cubic feet) per year. DOE estimated this breathing rate from data in International Commission on Radiological Protection Publication 23 (DIRS 101074-ICRP 1975, p. 346).

- The release from a severe accident would include only respirable material (DIRS 157144-Jason Technologies 2001, p. 177). The deposition velocity for respirable material would be 0.01 meter per second (0.022 mile per hour).

- A short-term exposure time to airborne contaminants of 2 hours.

- A long-term exposure time to contamination deposited on the ground of 1 year, with no interdiction or cleanup.

- In the Yucca Mountain FEIS, DOE used two sets of atmospheric conditions, neutral atmospheric conditions and moderate winds speeds, and stable atmospheric conditions and low wind speeds to determine consequences from severe accidents. Stable atmospheric conditions and low wind speeds yielded higher consequences than neutral atmospheric conditions and moderate wind speeds. Therefore, in this Repository SEIS, DOE used low wind speeds and stable atmospheric conditions [a wind speed of 0.89 meter per second (2 miles per hour) and Class F stability] to determine consequences. The atmospheric concentrations estimated from these atmospheric conditions would be exceeded only 5 percent of the time.

- The spent nuclear fuel assembly would have a burnup of 60,000 megawatt-days per MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 169061-BSC 2004, all). Table G-15 lists the radionuclide inventory for a single spent nuclear fuel assembly.

DOE used the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) to estimate radiation doses for the inhalation, groundshine, immersion, and resuspension pathways. RISKIND has been verified and validated for estimating radiation doses from transportation accidents involving radioactive material (DIRS 101845-Maheras and Pippen 1995, all; DIRS 102060-Biwer et al. 1997, all). In addition, DOE used the inhalation dose coefficients from DIRS 172935-ICRP (2001, all) and the groundshine and immersion dose coefficients from DIRS 175544-EPA (2002, all) to estimate radiation doses.

The analysis assumed that the severe transportation accidents could occur anywhere. Population densities in rural areas range from 0 to 139 people per square kilometer. DOE based the analysis in the rural area on a population density of 6 people per square kilometer, which is a representative population density for a rural area (DIRS 101892-NRC 1977, p. E-2). The Department estimated the population density in an urban area by identifying the 20 urban areas in the United States with the largest populations using 2000 Census data, determining the population density in successive annular rings around the center of each urban area, escalating these population densities to 2067, and averaging the population densities in each successive annular ring. Based on 2000 Census data, Las Vegas was not among the 20 largest urban areas in the United States. However, because of proximity of Las Vegas to the repository, DOE included it in the population density analysis. The resident population in Las Vegas was modified to include casino guests and casino workers. Table G-20 lists the population densities.

Table G-20. Population density in urban area.

Annular distance (kilometers)	Population density (people per square kilometer)
0 to 8.05 (0 to 5 miles)	5,012
8.05 to 16.09 (5 to 10 miles)	2,956
16.09 to 24.14 (10 to 15 miles)	2,112
24.14 to 32.19 (15 to 20 miles)	1,342
32.19 to 40.23 (20 to 25 miles)	899
40.23 to 80.47 (25 to 50 miles)	390

Note: Population densities have been escalated to 2067.

G.9 Transportation Sabotage

DOE used the following assumptions to estimate the consequences of transportation sabotage events (DIRS 157144-Jason Technologies 2001, Section 5.3.4.2):

- A breathing rate for individuals of 10,400 cubic meters (367,000 cubic feet) per year. This breathing rate was estimated from data in International Commission on Radiological Protection Publication 23 (DIRS 101074-ICRP 1975, p. 346).

- A short-term exposure time to airborne contaminants of 2 hours.

- A long-term exposure time to contamination deposited on the ground of 1 year, with no interdiction or cleanup.

- In the Yucca Mountain FEIS, DOE used neutral atmospheric conditions and moderate wind speeds to determine the consequences of sabotage events. In this Repository SEIS, DOE used moderate wind speeds and neutral atmospheric conditions [a wind speed of 4.47 meters per second (10 miles per hour) and Class D stability] to determine the consequences of sabotage.

- The release from a sabotage event would include respirable and nonrespirable material. The deposition velocity for respirable material would be 0.01 meter per second (0.022 mile per hour) and the deposition velocity for nonrespirable material would be 0.1 meter per second (0.22 mile per hour).

The DOE analysis assumed that in the sabotage event there would be an initial explosive release that involved releases of radioactive material at varying release heights. For 4 percent of the release, the analysis estimated a release height of 1 meter (3.3 feet); for 16 percent of the release, it estimated a release height of 16 meters (52 feet); for 25 percent of the release, it estimated a release height of 32 meters (105 feet); for 35 percent of the release, it estimated a release height of 48 meters (160 feet); and for 20 percent of the release, it estimated a release height of 64 meters (210 feet) (DIRS 157144-Jason Technologies 2001, p. 189).

In the Yucca Mountain FEIS, DOE used the release fraction data in Luna et al. (DIRS 104918-Luna et al. 1999, all) to evaluate the consequences of sabotage events. For truck and rail casks, a successful sabotage attempt that used the device called “high energy density device one” yielded the largest radiation doses. In this Repository SEIS, the Department used release fractions from Luna (DIRS 181279-Luna 2006, all) to estimate the impacts of such acts that involved spent nuclear fuel in truck or rail casks. The release fractions in Luna (DIRS 181279-Luna 2006, all) are based on the release fractions in Luna et al. (DIRS 104918-Luna et al. 1999, all), but they incorporate data from additional tests sponsored by *Gesellschaft für Anlagen - und Reaktorsicherheit* in Germany and conducted in France in 1994 that were not available for the 1999 report. These tests used pressurized fuel pins and provided a means to assess the effects of aerosol blowdown from pin plenum gas release. The use of these additional test data suggest that DOE overstated the consequences in the FEIS by a factor of 2.5 to 12.

For rail casks, the release fractions in Luna (DIRS 181279-Luna 2006, all) and Luna et al. (DIRS 104918-Luna et al 1999, all) were based on a rail cask that would hold 26 pressurized-water reactor spent nuclear fuel assemblies. DOE plans to operate the repository using a primarily canistered approach that calls for packaging most commercial spent nuclear fuel in TAD canisters, which would hold 21 pressurized-water reactor spent nuclear fuel assemblies. In this Repository SEIS, DOE chose to estimate the consequences of a rail sabotage event based on the radionuclide inventory in 26 pressurized-water reactor spent nuclear fuel assemblies, which overestimated consequences by about 24 percent in comparison to the inventory in 21 pressurized-water reactor spent nuclear fuel assemblies. For truck casks, the sabotage scenario involved a single truck cask that contained four pressurized-water reactor spent nuclear fuel assemblies. Table G-15 lists the radionuclide inventory for a single pressurized-water reactor spent nuclear fuel assembly.

DOE used the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) to estimate radiation doses for the inhalation, groundshine, immersion, and resuspension pathways. The analysis assumed that the transportation sabotage event could occur anywhere, either in rural or urban areas, using the same population densities as those in the severe accident analysis in Section G.8.

G.10 Transportation Topical Areas

This section discusses topics identified by the public during the scoping process for this Repository SEIS and the Rail Alignment EIS.

G.10.1 ACCIDENTS INVOLVING HAZARDOUS CHEMICALS

DOE would use dedicated trains to ship most spent nuclear fuel and high-level radioactive waste, and hazardous chemical cargos would not be on the same train as spent nuclear fuel or high-level radioactive waste. This would greatly reduce the potential for accidents involving the spent nuclear fuel or high-level radioactive waste and hazardous chemicals.

G.10.2 CRITICALITY DURING ACCIDENTS

Criticality is the term used to describe an uncontrolled nuclear chain reaction. NRC regulations in 10 CFR Part 71 require that the casks used to ship spent nuclear fuel and high-level radioactive waste be able to survive accident conditions, such as immersion in water, without undergoing a criticality. To meet this requirement, casks are typically designed such that, even if water filled the cask and the cask contained unirradiated nuclear fuel (the most reactive case from the perspective of a criticality), a criticality would not occur.

G.10.3 AIRCRAFT CRASH

An aircraft crash into a spent nuclear fuel or high-level radioactive waste cask would be extremely unlikely because the probability of a crash into such a relatively small object, whether stationary or moving, is extremely remote. Nevertheless, the Yucca Mountain FEIS analyzed the consequences of an accident in which a large commercial aircraft or a military aircraft is hypothesized to impact directly onto a cask (DIRS 155970-DOE 2002, Section J.3.3.1). The analysis showed that the penetrating force of a jet engine's center shaft would not breach the heavy shield wall of a cask. With the exception of engines, the relatively light structures of an aircraft would be much less capable of causing damage to a cask. A resulting fire would not be sustainable or able to engulf a cask long enough to breach its integrity.

The *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all), and the *Final Environmental Impact Statement, Withdrawal of Public Lands for Range Safety and Training Purposes, Naval Air Station Fallon, Nevada* (DIRS 148199-USN 1998, all) discussed system malfunctions or material failures that could result in either an accidental release of ordnance or release of a practice weapon. The *Special Nevada Report* (DIRS 153277-SAIC 1991, all) stated that the probability of dropped ordnance that resulted in injury, death, or property damage ranges from about 1 in 1 billion to 1 in 1 trillion per dropped ordnance incident, with an average of about 1 in 10 billion per incident. Less than one accidentally dropped ordnance incident is estimated per year for all flight operations over the Nevada Test and Training Range and Naval Air Station Fallon. Spent nuclear fuel transportation would not affect the risk from dropped ordnance or aircraft crashes. Therefore, this Repository SEIS does not evaluate radiological consequences of an impact of accidentally dropped ordnance on a shipping cask because the probability of such an event (about 1 in 10 billion per year) is not reasonably foreseeable. Therefore, DOE believes there would be no need for associated mitigation measures and no impacts on military operations.

G.10.4 BALTIMORE TUNNEL FIRE

On July 18, 2001, a freight train carrying hazardous (nonnuclear) materials derailed and caught fire while passing through the Howard Street railroad tunnel in downtown Baltimore, Maryland. The NRC evaluated possible impacts of this fire in *Spent Nuclear Fuel Transportation Package Response to the Baltimore Tunnel Fire Scenario* (DIRS 182014-Adkins et al. 2006, all).

This study evaluated the response of three transportation casks—the HOLTEC Model No. HI-STAR 100, the TransNuclear Model No. TN-68, and the Nuclear Assurance Corporation Legal Weight Truck—to the conditions that existed during the fire. The study concluded that larger transportation packages that resembled the HI-STAR 100 and TN-68 would withstand a fire with thermal conditions similar to those that existed in the Baltimore tunnel fire event with only minor damage to peripheral components. This would be due to their sizable thermal inertia and design specifications in compliance with currently imposed regulatory requirements.

For the TN-68 and the Nuclear Assurance Corporation Legal Weight Truck casks, the maximum temperatures predicted in the regions of the lid and the vent and drain ports exceed the seals' rated service temperatures, making it possible for a small release to occur due to crud that might spall off the surfaces of the fuel rods. While a release is not expected for these conditions, any release that could occur would be very small due to the following factors: (1) the tight clearances maintained between the lid and cask body by the closure bolts, (2) the low pressure differential between the cask interior and exterior, (3) the tendency of such small clearances to plug, and (4) the tendency of crud particles to settle or plate out.

The NRC study also evaluated the radiological consequences of the package responses to the Baltimore tunnel fire. The analysis indicated that the regulatory dose rate limits specified in 10 CFR 71.51 for accident conditions would not be exceeded by releases or direct radiation from any of these packages in this fire scenario. All three packages are designed to maintain regulatory dose rate limits even with a complete loss of neutron shielding. While highly unlikely, the Nuclear Assurance Corporation Legal Weight Truck cask could experience some decrease in gamma shielding due to slump in the lead as a consequence of this fire scenario, but a conservative analysis showed that the regulatory dose rate limits would not be exceeded.

The results of this evaluation strongly indicate that neither spent nuclear fuel particles nor fission products would be released from a spent fuel shipping cask carrying intact spent nuclear fuel involved in a severe tunnel fire such as the Baltimore Tunnel Fire. None of the three cask designs analyzed for the Baltimore Tunnel fire scenario (TN-68, HI-STAR 100, and Nuclear Assurance Corporation Legal Weight Truck) experienced internal temperatures that would result in rupture of the fuel cladding. Therefore, radioactive material (spent nuclear fuel particles or fission products) would be retained in the fuel rods.

There would be no release from the HI-STAR 100 because the inner welded canister would remain leak tight. While a release is unlikely, the potential releases calculated for the TN-68 rail cask and the Legal Weight Truck cask indicated that any release of crud from either cask would be very small—less than 5 rem.

The NRC also evaluated the response of the Nuclear Assurance Corporation Legal Weight Truck cask to the conditions present during the Caldecott Tunnel fire in *Spent Fuel Transportation Package Response to the Caldecott Tunnel Fire Scenario* (DIRS 181841-Adkins et al. 2007, all). This fire took place on April 7, 1982, when a tank truck and trailer carrying 8,800 gallons of gasoline was involved in an accident in the Caldecott Tunnel on State Route 24 near Oakland, California. The trailer overturned and subsequently caught fire. This event is one of the most severe of the five major highway tunnel fires involving shipments of hazardous material that have occurred world-wide since 1949.

This study concluded that small transportation casks similar to the Nuclear Assurance Corporation Legal Weight Truck cask would probably experience degradation of some seals in this severe accident scenario. The maximum temperatures predicted in the regions of the cask lid and the vent and drain ports exceed the rated service temperature of the tetrafluoroethylene or Viton seals, making it possible for a small release to occur due to crud that could spall off the surfaces of the fuel rods. However, any release is expected to be very small due to a number of factors: (1) the metallic lid seal does not exceed its rated service temperature and therefore can be assumed to remain intact, (2) the tight clearances maintained by the lid closure bolts, (3) the low pressure differential between the cask interior and exterior, (4) the tendency for solid particles to plug small clearance gaps and narrow convoluted flow paths such as the vent and drain ports, and (5) the tendency of crud particles to settle or plate out and, therefore, not be available for release.

The NRC study also evaluated the radiological consequences of the package response to the Caldecott Tunnel fire. The results of this evaluation strongly indicate that neither spent nuclear fuel particles nor fission products would be released from a spent fuel shipping cask involved in a severe tunnel fire such as the Caldecott Tunnel fire. The Nuclear Assurance Corporation Legal Weight Truck cask design analyzed for the Caldecott Tunnel fire scenario does not reach internal temperatures that could result in rupture of the fuel cladding. Therefore, radioactive material (spent nuclear fuel particles or fission products) would be retained in the fuel rods. The potential release calculated for the Legal Weight Truck cask in this scenario indicates that any release of crud from the cask would be very small—less than 5 rem.

G.10.5 CASK RECOVERY

The recovery of rail casks loaded with spent nuclear fuel or high-level radioactive waste would use methods commonly used to recover railcars and locomotives following accidents. The capability to lift such weights exists and would be deployed as required. Railroads use emergency response contractors with the ability to lift derailed locomotives that could weigh as much as 136 metric tons (150 tons). Difficult recoveries of equipment as heavy as spent nuclear fuel casks have occurred and DOE anticipates that, if such a recovery was necessary, it would use methods and equipment similar to those used in prior difficult recoveries.

G.10.6 HUMAN ERROR AND TRANSPORTATION ACCIDENTS

The conditional probabilities and release fractions discussed in Section G.7.1.2 would be mostly a direct consequence of error on the part of transport vehicle operators, operators of other vehicles, or persons who maintained vehicles and rights-of-way. The number and severity of the accidents would be minimized through the use of trained and qualified personnel.

Others have argued that other types of human error could contribute to accident consequences: (1) undetected error in the design and certification of transportation packaging (casks) used to ship radioactive material, (2) hidden or undetected defects in the manufacture of these packages, and (3) error in the preparation of the packages for shipment. DOE has concluded that regulations and regulatory practices of the NRC and the U.S. Department of Transportation address the design, manufacture, and use of transportation packaging and are effective in the prevention of these kinds of human error by requiring:

- Independent NRC review of designs to ensure compliance with requirements (10 CFR Part 71), and
- NRC-approved and -audited quality assurance programs for design, manufacturing, and use of transportation packages.

In addition, federal provisions (10 CFR Part 21) provide additional assurance of timely and effective actions to identify and initiate corrective actions for undetected design or manufacturing defects. Further, conservatism in the approach to safety in the regulatory requirements and practices provides confidence that design or manufacturing defects that might remain undetected or operational deficiencies would not lead to a meaningful reduction in the performance of a package under normal or accident conditions of transportation.

G.10.7 COST OF CLEANUP

According to the NRC report *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7 to 76), in more than 99.99 percent of accidents radioactive material would not be released from the cask. After initial safety precautions had been taken, the cask would be recovered and removed from the accident scene. Because no radioactive material would be released, based on reported experience with two previous accidents (DIRS 156110-FEMA 2000, Appendix G, Case 4 and Case 5), the economic costs of these accidents would be minimal.

For the 0.01 percent of accidents severe enough to cause a release of radioactive material from a cask, a number of interrelated factors would affect costs of cleaning up the resulting radioactive contamination after the accident: the severity of the accident and the initial level of contamination; the weather at the time and following; the location and size of the affected land area and the use of the land; the established standard for the allowable level of residual contamination following cleanup and the decontamination method used; and the technical requirements and location for disposal of contaminated materials.

Because it would be necessary to specify each of the factors to estimate cleanup costs, an estimate for a single accident would be highly uncertain and speculative. Nevertheless, to provide a gauge of the costs that could occur DOE examined past studies of costs of cleanup following hypothetical accidents that would involve uncontrolled releases of radioactive materials.

An NRC study of the impacts of transporting radioactive materials in 1977 estimated that costs could range from about $1 million to $100 million for a transportation accident that involved a 600-curie release of a long-lived radionuclide (DIRS 101892-NRC 1977, Table 5-11). These estimates would be about 3 times higher if escalated for inflation from 1977 to the present. In 1980, Finley et al. (DIRS 155054-Finley et al. 1980, Table 6-9) estimated that costs could range from about $90 million to $2 billion for a severe spent nuclear fuel transportation accident in an urban area. Sandquist et al. (DIRS 154814-Sandquist et al. 1985, Table 3-7) estimated that costs could range from about $200,000 to $620 million. In this study, Sandquist et al. estimated that contamination would affect between 0.063 to 4.3 square kilometers (16 to 1,100 acres). A study by Chanin and Murfin (DIRS 152083-Chanin and Murfin 1996, Chapter 6) estimated the costs of cleanup following a transportation accident in which plutonium was dispersed. This study developed cost estimates for cleaning up and remediating farmland, urban areas, rangeland, and forests. The estimates ranged from $38 million to $400 million per square kilometer that would need cleanup. In addition, the study evaluated the costs of expedited cleanups in urban areas for light, moderate, and heavy contamination levels. These estimates ranged from $89 million to $400 million per square kilometer.

The National Aeronautics and Space Administration studied potential accidents for the Cassini mission, which used a plutonium powered electricity generator. The Administration estimated costs of cleaning up radioactive material contamination on land following potential launch and reentry accidents. The estimate for the cost following a launch accident ranged from $7 million to $70 million (DIRS 155551-NASA 1995, Chapter 4) with an estimated contaminated land area of about 1.4 square kilometers (350 acres). The Administration assumed cleanup costs would be $5 million per square kilometer if removal and disposal of contaminated soil were not required and $50 million per square kilometer if those activities were required. For a reentry accident that occurred over land, the study estimated that the contaminated area could range from about 1,500 to 5,700 square kilometers (370,000 to 1.4 million acres) (DIRS 155551-NASA 1995, Chapter 4) with cleanup costs possibly exceeding a total of $10 billion. In a more recent study of potential consequences of accidents that could involve the Cassini mission, the Administration estimated that costs could range from $7.5 million to $1 billion (DIRS 155550-NASA 1997, Chapter 4). The contaminated land area associated with these costs ranged from 1.5 to 20 square kilometers (370 to 4,900 acres). As in the 1995 study, these estimates were based on cleanup costs in the range of $5 million to $50 million per square kilometer.

Using only the estimates provided by these studies, the costs of cleanup following a severe transportation accident that involved spent nuclear fuel in which radioactive material was released could be in the range from $300,000 (after adjusting for inflation from 1985 to the present) to $10 billion. Among the reasons for this wide range are different assumptions about the factors that must be considered: (1) the severity of the assumed accident and resulting contamination levels, (2) accident location and use of affected land areas, (3) meteorological conditions, (4) cleanup levels and decontamination methods, and (5) disposal of contaminated materials. However, the extreme high estimates of costs are based on assumptions that all factors combine in the most disadvantageous way to create a worst case. Such worst cases are not reasonably foreseeable. Conversely, estimates as low as $300,000 might not be realistic for all of the direct and indirect costs of cleaning up following an accident severe enough to cause a release of radioactive materials.

To gauge the range of costs that it could expect for severe accidents during the transport of spent nuclear fuel to a Yucca Mountain repository, DOE considered the amount of radioactive material that could be released in the maximum reasonably foreseeable accident and compared this to the estimates of releases used in the studies discussed above. The maximum reasonably foreseeable accident would release about 30 curies (mostly cesium). This is about 50 times less than the release used by Sandquist et al. (DIRS 154814-Sandquist et al. 1985, all) (1,630 curies) and 20 times less than the release used in the estimates provided by the NRC in 1977 (600 curies). The estimated frequency for an accident this severe to occur is about 6 or 7 times in 10 million years. Based on the prior studies (in which estimated releases exceeded those estimated in this appendix for a maximum reasonably foreseeable accident) and the amount of radioactive material that could be released in a maximum reasonably foreseeable accident, DOE believes that the cost of cleaning up following such an accident could be a few million dollars. Nonetheless, as stated above, the Department also believes that estimates of such costs contain great uncertainty and are speculative; they could be less or 10 times greater, depending on the contributing factors.

For perspective, the current insured limit of responsibility for an accident that involves releases of radioactive materials to the environment is $10.26 billion (Appendix H).

OPPOSING VIEW: COSTS OF CLEANUP

The State of Nevada has provided analyses that assert that the costs of cleanup could be much higher than the estimates discussed in this Repository SEIS, up to $189.7 billion for accidents that involved rail casks (DIRS 181756-Lamb et al. 2001, p. 48) and up to $299.4 billion for sabotage that involved a rail cask (DIRS 181892-Lamb et al. 2002, p. 15).

DOE believes that these extremely high estimates of costs are based on assumptions that all factors combine in the most disadvantageous way to create a worst case. Such worst cases are not reasonably foreseeable.

G.10.8 UNIQUE LOCAL CONDITIONS

Scoping comments on this Repository SEIS stated the unique local conditions in Nevada require special consideration in the transportation accident analysis. In this SEIS, DOE analyzed a range of accidents that reflect the range of reasonably foreseeable real-life conditions. Real-life conditions that would involve various types of collisions, various natural disasters, specific locations (such as mountain passes), or various infrastructure accidents (such as track failure) in effect constitute a combination of cask failure mechanisms, impact velocities, and temperature ranges, which the EIS does evaluate. Because it is impossible to predict what real-life conditions might be involved in accidents that could occur, and to ensure that the analysis accounts for all reasonably foreseeable real-life conditions, DOE has described the maximum reasonably foreseeable accident in terms of cask failure mechanisms and accident forces. Accident scenarios are modeled in this fashion to accommodate the almost infinite number of variables that any given accident could involve.

G.10.9 COMPREHENSIVE RISK ASSESSMENT

The State of Nevada recommended that DOE should use comprehensive risk assessment as a substitute for probabilistic risk assessment in the transportation analysis. According to the state, comprehensive risk assessment calculates probabilities only if there are existing data, theories, and models to support use of rigorous quantitative methods, and uses sensitivity analysis to illustrate impacts of differing assumptions and variations in the quality of data.

Probabilistic risk assessment has been and continues to be the standard tool used for transportation risk assessments since the NRC published the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* in 1977 (DIRS 101892-NRC 1977, all). DOE used probabilistic risk assessment to estimate transportation impacts in this Repository SEIS because there are adequate data, methods, and computer programs that make it a valid, state-of-the-art tool to estimate transportation impacts. In addition, DOE has performed sensitivity analyses related to transportation impacts; these analyses are discussed in Appendix A.

G.10.10 BARGE SHIPMENTS

DOE evaluated the impacts of barge shipments of spent nuclear fuel in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Section J.2.4) for those generator sites without direct rail access but with barge access. The impacts of the use of barges to ship spent nuclear fuel from the generator sites with direct rail access were similar to the those of using heavy-haul trucks to ship from the generator sites without direct rail access for the mostly rail scenario (DIRS 155970-DOE 2002, Tables J-29, J-30, and J-32). The estimated exposed population along the barge routes analyzed in the FEIS would be 502,132 people (DIRS 157144-Jason Technologies 2001, Table 3-10).

For this Repository SEIS, DOE used the TRAGIS computer program to reevaluate the representative routes that could be used for barge shipments of spent nuclear fuel (DIRS 181276-Johnson and Michelhaugh 2003, all). Table G-21 lists the sites, the locations of the intermodal transfer between the barge and the railroad, the lengths of the barge route, and the exposed populations along the barge route. In some cases, DOE evaluated multiple locations for the intermodal transfer.

For the 15 generator sites without direct rail access but with barge access listed in Table G-21, the estimated exposed population along the barge routes would range from 199,193 to 418,945 people. This exposed population would be less than or similar to the exposed population estimated in the Yucca Mountain FEIS. The locations of the intermodal transfer between the barge and the railroad were similar to the locations analyzed in the FEIS (DIRS 155970-DOE 2002, Table J-27) and the distances were similar to the distances estimated in the FEIS (DIRS 155970-DOE 2002, Table J-26). Because the exposed populations, distances, and intermodal transfer locations were similar to the exposed populations,

Table G-21. Data used in reevaluation of barge shipments.

Site	Distance (kilometers)	Exposed population	Barge port assumed for barge-to-rail intermodal transfer
Browns Ferry	6.9	1	Port of Decatur
Browns Ferry	65.2	1,458	Port of Sheffield
Diablo Canyon	249.7	1,514	Port Hueneme
Haddam Neck	75.1	3,557	Port of New Haven
Haddam Neck	55.8	3,593	Port of New London
St. Lucie	141.2	155,517	Port Everglades
St. Lucie	175.0	204,530	Port of Miami
St. Lucie	20.7	355	Port of Fort Pierce
Calvert Cliffs	110.8	2,213	Port of Baltimore
Calvert Cliffs	189.1	63	Port of Norfolk
Palisades	102.4	16	Port of Muskegon
Grand Gulf	51.6	32	Port of Vicksburg
Cooper	117.1	2,780	Port of Omaha
Hope Creek	30.3	85	Port of Wilmington
Hope Creek	69.5	1,159	Port of Philadelphia
Hope Creek	131.6	6,052	Port of Baltimore
Oyster Creek	131.3	43,595	Port of Newark
Salem	31.6	85	Port of Wilmington
Salem	70.8	1,159	Port of Philadelphia
Salem	132.9	6,052	Port of Baltimore
Indian Point	89.6	59,215	Port of Newark
Surry	59.8	43	Port of Norfolk
Kewaunee	149.0	43,977	Port of Milwaukee
Point Beach	142.5	43,875	Port of Milwaukee
Total	1,349.1 – 1,861.9	199,193 – 418,945	

Note: Conversion factors are on the inside back cover of this Repository SEIS.

distances, and intermodal transfer locations analyzed in the FEIS, the impacts of using barge shipments would be similar to the impacts of using barge shipments in the FEIS, and DOE did not evaluate barge shipments further in this Repository SEIS.

G.10.11 USE OF NUREG/CR-6672 TO ESTIMATE ACCIDENT RELEASES

The evaluations of the radiological impacts of transportation accidents in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Chapter 6) are based on data in NUREG/CR-6672 (*Reexamination of Spent Nuclear Fuel Shipment Risk Estimates*, DIRS 152476-Sprung et al. 2000, all) on conditional probabilities for the occurrence of severe accidents and on corresponding fractions of cask contents that could be released in such accidents.

In September 1977, the NRC issued a generic EIS, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NUREG-0170; DIRS 101892-NRC 1977, all). This EIS addressed environmental impacts associated with the transport of all types of radioactive material by all transport modes (road, rail, air, and water). It provided the basis under NEPA for the NRC to issue general licenses for transportation of radioactive material under 10 CFR Part 71. Based in part on the findings of the EIS, the NRC concluded that “present regulations are adequate to protect the public against unreasonable risk from the transport of radioactive materials” (46 FR 21629, April 13, 1981) and stated that “regulatory policy concerning transportation of radioactive materials be subject to close and continuing review.”

In 1996, the NRC decided to reexamine the risks associated with the shipment of spent power reactor fuel by truck and rail to determine if the estimates of environmental impacts in NUREG-0170 (DIRS 101892-NRC 1977, all) remained valid. According to the Commission, the reexamination was initiated because (1) many spent fuel shipments are expected to be made during the next few decades, (2) these shipments will be made to facilities along routes and in casks not specifically examined by NUREG-0170, and (3) the risks associated with these shipments can be estimated using new data and improved methods of analysis. In 2000, the NRC published the results of the reexamination in a report prepared by the Sandia National Laboratories, *Reexamination of Spent Nuclear Fuel Shipment Risk Estimates* (NUREG/CR-6672; DIRS 152476-Sprung et al. 2000, all).

Some have been critical of NUREG/CR-6672 (DIRS 152476-Sprung et al. 2000, all) [for example, see DIRS 181884-Lamb and Resnikoff (2000, all) and Appendix A in DIRS 181756-Lamb et al. (2001, Appendix A]. However, the NRC has stated that that many of the purported methodological flaws appear to be related to differing views on assumptions and that critical comments do not appear to recognize that many of the assumptions overstated risks (DIRS 181603-Shankman 2001, all).

Supporting the NRC assessment, in its review of NUREG/CR-6672 (DIRS 152476-Sprung et al. 2000, all) (see *Going the Distance? The Safe Transport of Spent Nuclear and High-Level Radioactive Waste in the United States*; DIRS 182032-National Research Council 2006, all), the National Academy of Sciences Committee on Transportation of Radioactive Waste noted that the conservative assumptions were reasonable for producing bounding estimates of accident consequences. Conversely, the Committee indicated less confidence about the analysis of overall transport risks in the report. The Committee noted that the truck and rail routes used in the analyses were based on realistic, not bounding characteristics. The Committee considered “many other uncertainties” and ultimately concluded that the overall results of the “Sandia analyses are likely to be neither realistic nor bounding and ‘probably’ overestimate transport risks.”

Based on the review by the National Academy of Sciences and comments made by NRC, DOE has concluded that NUREG/CR-6672 (DIRS 152476-Sprung et al. 2000, all) represents best available information for use in estimating the consequences of transportation accidents that involve spent nuclear fuel and high-level radioactive waste and has used it in this Repository SEIS.

G.11 State-Specific Impacts and Route Maps

This section contains tables (G-22 through G-66) and maps (Figures G-3 through G-47) that illustrate the estimated impacts to 44 states and the District of Columbia (Alaska and Hawaii are not included; estimated impacts in Delaware, Montana, North Dakota, and Rhode Island would be zero). As discussed above, DOE used state- and route-specific data to estimate transportation impacts. At this time, about 10 years before shipments could begin, DOE has not determined the specific routes it would use to ship spent nuclear fuel and high-level radioactive waste to the proposed repository. Therefore, the transportation routes discussed in this section might not be the exact routes used for shipments to Yucca Mountain. Nevertheless, because the analysis is based primarily on the existing Interstate Highway System and the existing national rail network, the analysis presents a representative estimate of what the actual transportation impacts would probably be.

Table G-22. Estimated transportation impacts for the State of Alabama.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,514	3.9	62	0.0024	0.037	0.0030	0.011	6.3×10^{-6}	0.0087	0.052
Truck	857	4.7	7.5	0.0028	0.0045	0.0018	9.0×10^{-4}	5.4×10^{-7}	0.0052	0.014
Total	2,371	8.7	70	0.0052	0.042	0.0047	0.011	6.9×10^{-6}	0.014	0.066
Mina										
Rail	1,514	3.9	62	0.0024	0.037	0.0030	0.011	6.3×10^{-6}	0.0087	0.052
Truck	857	4.7	7.5	0.0028	0.0045	0.0018	9.0×10^{-4}	5.4×10^{-7}	0.0052	0.014
Total	2,371	8.7	70	0.0052	0.042	0.0047	0.011	6.9×10^{-6}	0.014	0.066

a. Totals might differ from sums of values due to rounding.

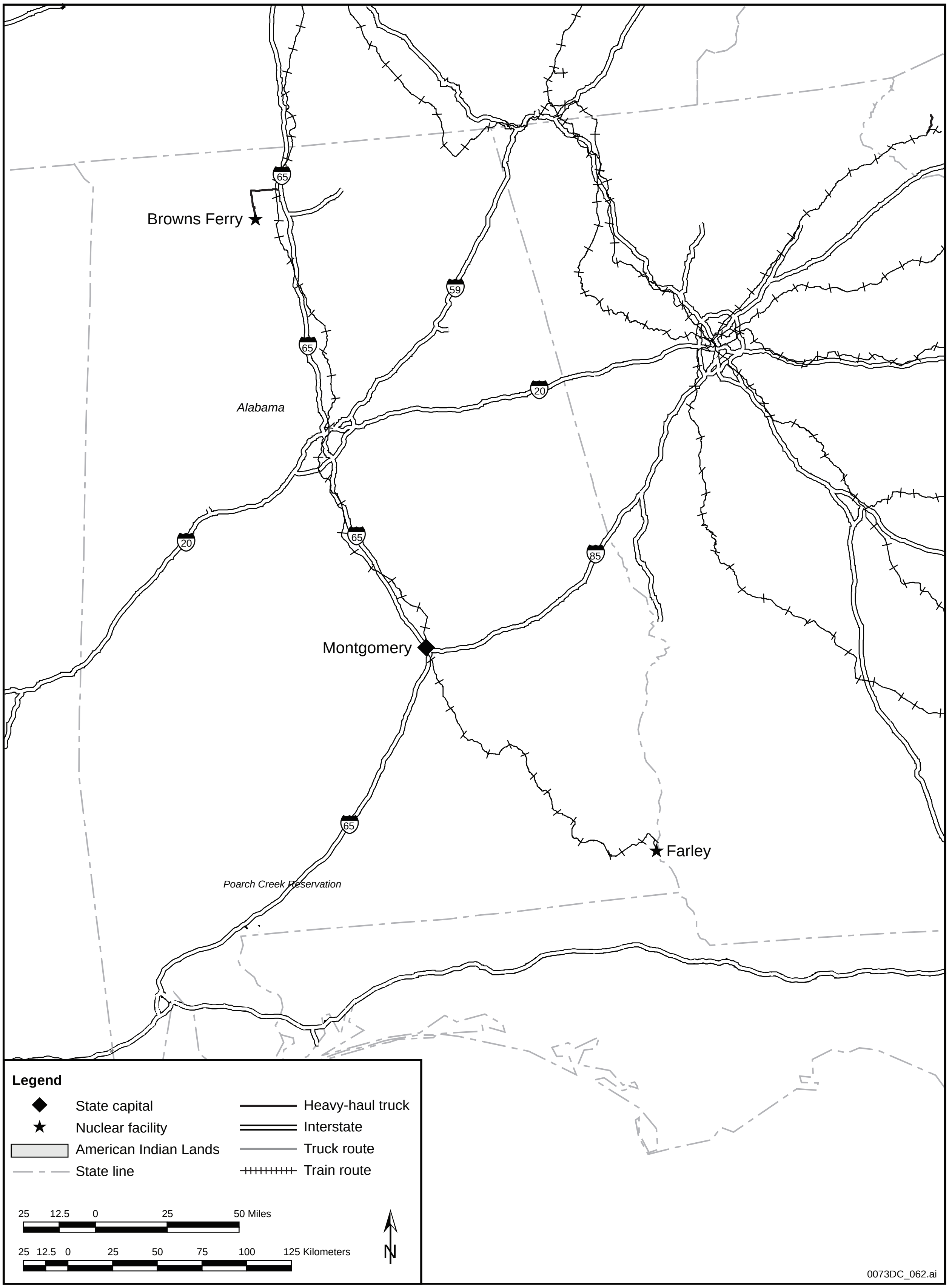

Figure G-3. Representative transportation routes for the State of Alabama.

Table G-23. Estimated transportation impacts for the State of Arizona.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	456	18	35	0.011	0.021	0.025	0.092	5.5×10^{-5}	0.016	0.073
Truck	2,650	15	38	0.0090	0.023	0.0055	0.0013	7.9×10^{-7}	0.029	0.066
Total	3,106	33	74	0.020	0.044	0.030	0.093	5.6×10^{-5}	0.045	0.14
Mina										
Rail	357	15	30	0.0092	0.018	0.021	0.077	4.6×10^{-5}	0.013	0.060
Truck	2,650	15	38	0.0090	0.023	0.0055	0.0013	7.9×10^{-7}	0.029	0.066
Total	3,007	30	68	0.018	0.041	0.026	0.078	4.7×10^{-5}	0.041	0.13

a. Totals might differ from sums of values due to rounding.

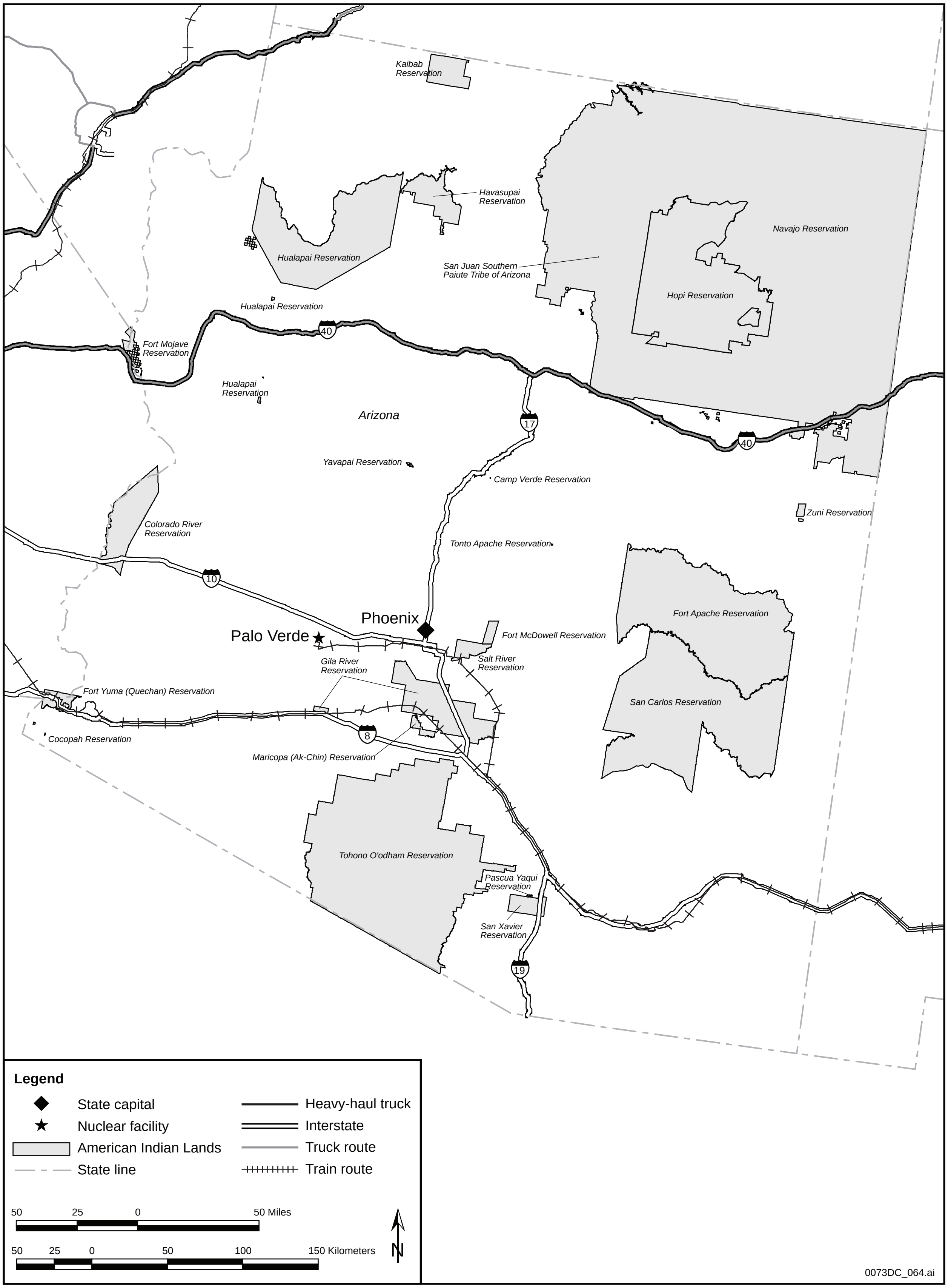

Figure G-4. Representative transportation routes for the State of Arizona.

Table G-24. Estimated transportation impacts for the State of Arkansas.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098
Truck	0	0	0	0	0	0	0	0	0	0
Total	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098
Mina										
Rail	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098
Truck	0	0	0	0	0	0	0	0	0	0
Total	227	0.46	11	2.7×10^{-4}	0.0063	6.7×10^{-4}	0.0035	2.1×10^{-6}	0.0026	0.0098

a. Totals might differ from sums of values due to rounding.

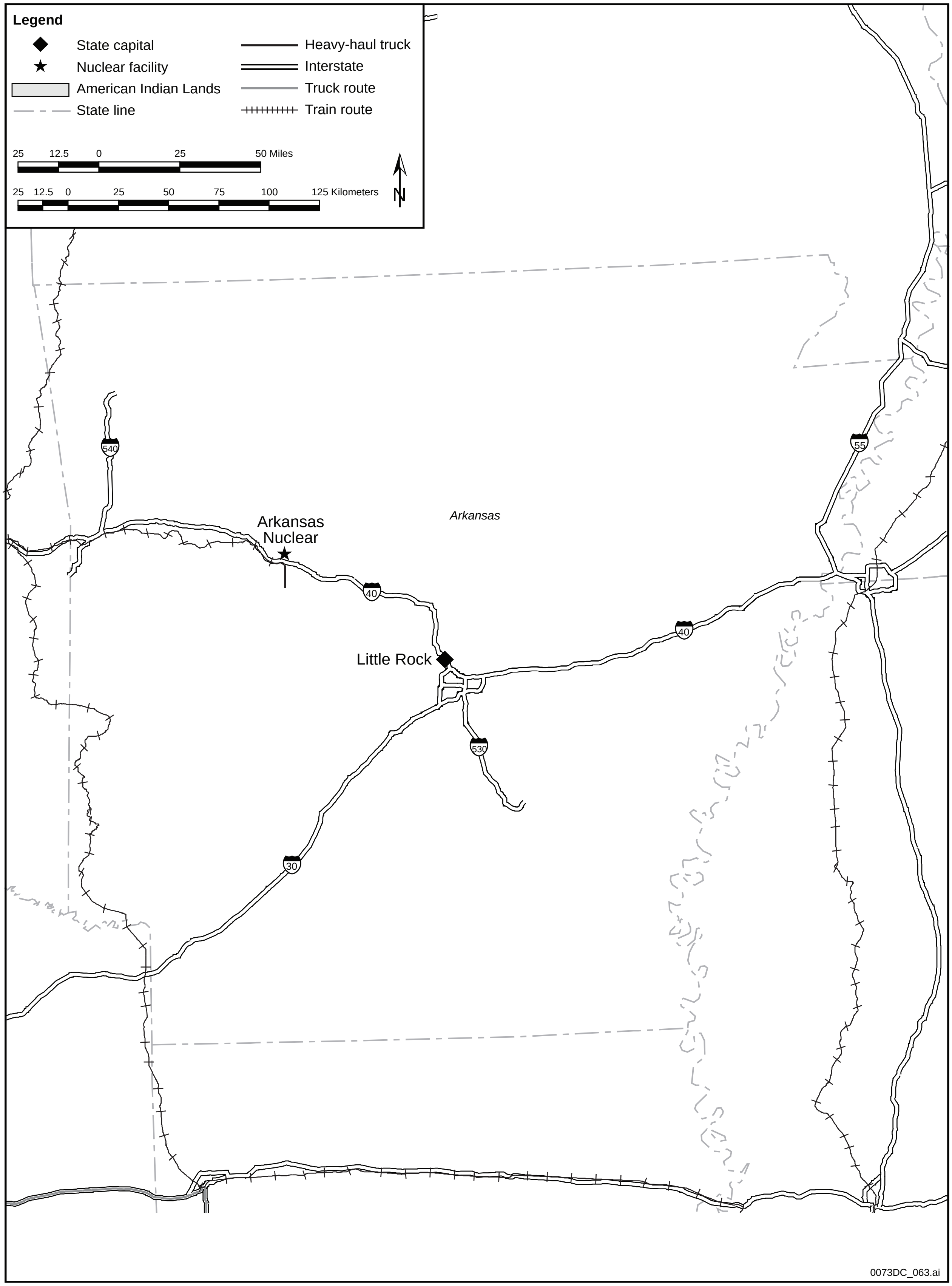

Figure G-5. Representative transportation routes for the State of Arkansas.

Table G-25. Estimated transportation impacts for the State of California.

Rail alignment	No. of Casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	755	35	82	0.021	0.049	0.042	0.16	9.9×10^{-5}	0.032	0.14
Truck	857	7.6	24	0.0045	0.015	0.0010	3.1×10^{-4}	1.9×10^{-7}	0.015	0.036
Total	1,612	43	110	0.026	0.064	0.043	0.16	9.9×10^{-5}	0.047	0.18
Mina										
Rail	1,963	99	160	0.059	0.098	0.12	0.35	2.1×10^{-4}	0.087	0.36
Truck	857	7.6	24	0.0045	0.015	0.0010	3.1×10^{-4}	1.9×10^{-7}	0.015	0.036
Total	2,820	110	190	0.064	0.11	0.12	0.35	2.1×10^{-4}	0.10	0.40

a. Totals might differ from sums of values due to rounding.

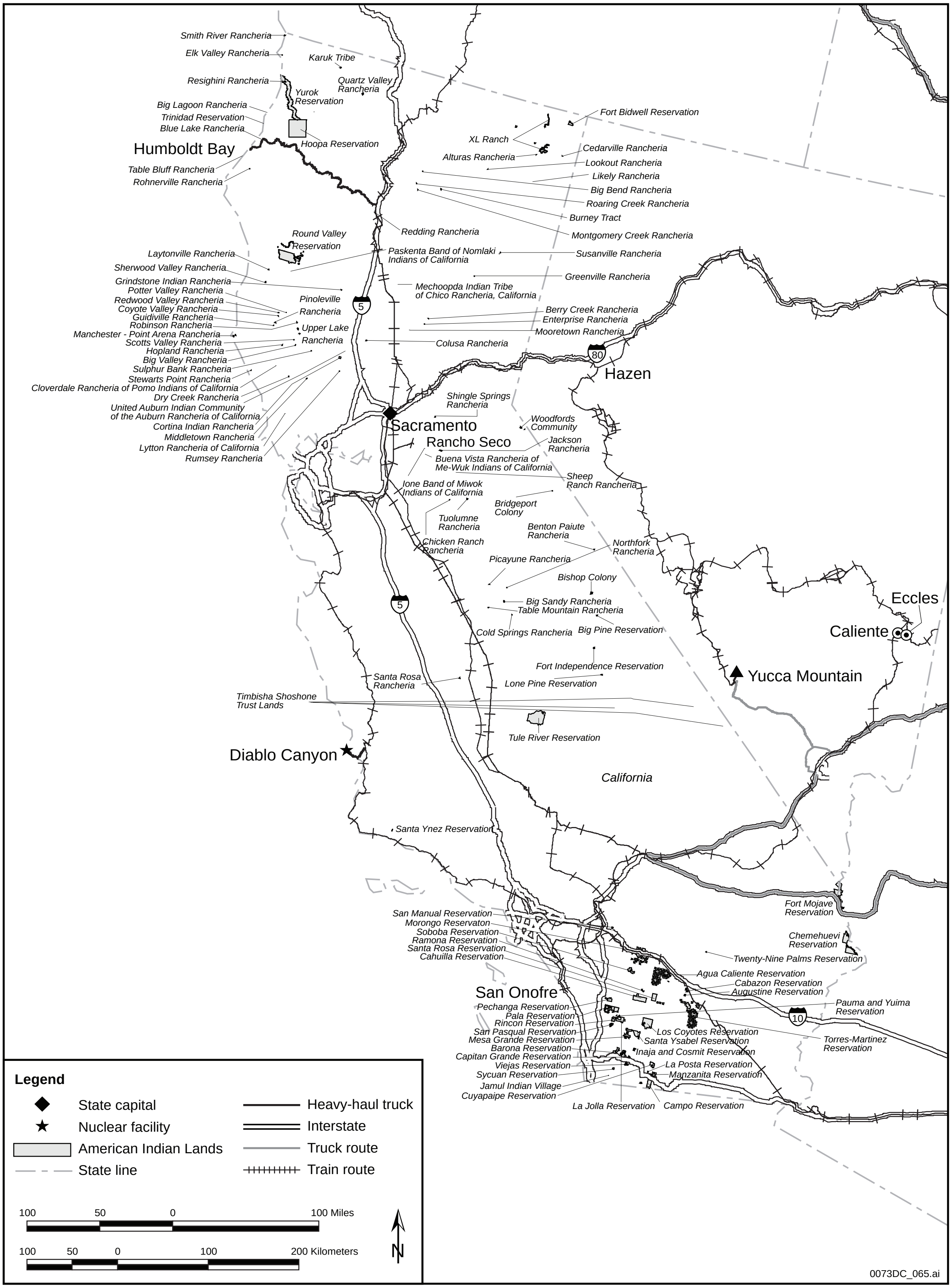

Figure G-6. Representative transportation routes for the State of California.

Table G-26. Estimated transportation impacts for the State of Colorado.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,739	6.8	35	0.0041	0.021	0.010	0.055	3.3×10^{-5}	0.024	0.059
Truck	0	0	0	0	0	0	0	0	0	0
Total	6,739	6.8	35	0.0041	0.021	0.010	0.055	3.3×10^{-5}	0.024	0.059
Mina										
Rail	6,838	9.4	43	0.0056	0.026	0.014	0.068	4.1×10^{-5}	0.029	0.075
Truck	0	0	0	0	0	0	0	0	0	0
Total	6,838	9.4	43	0.0056	0.026	0.014	0.068	4.1×10^{-5}	0.029	0.075

a. Totals might differ from sums of values due to rounding.

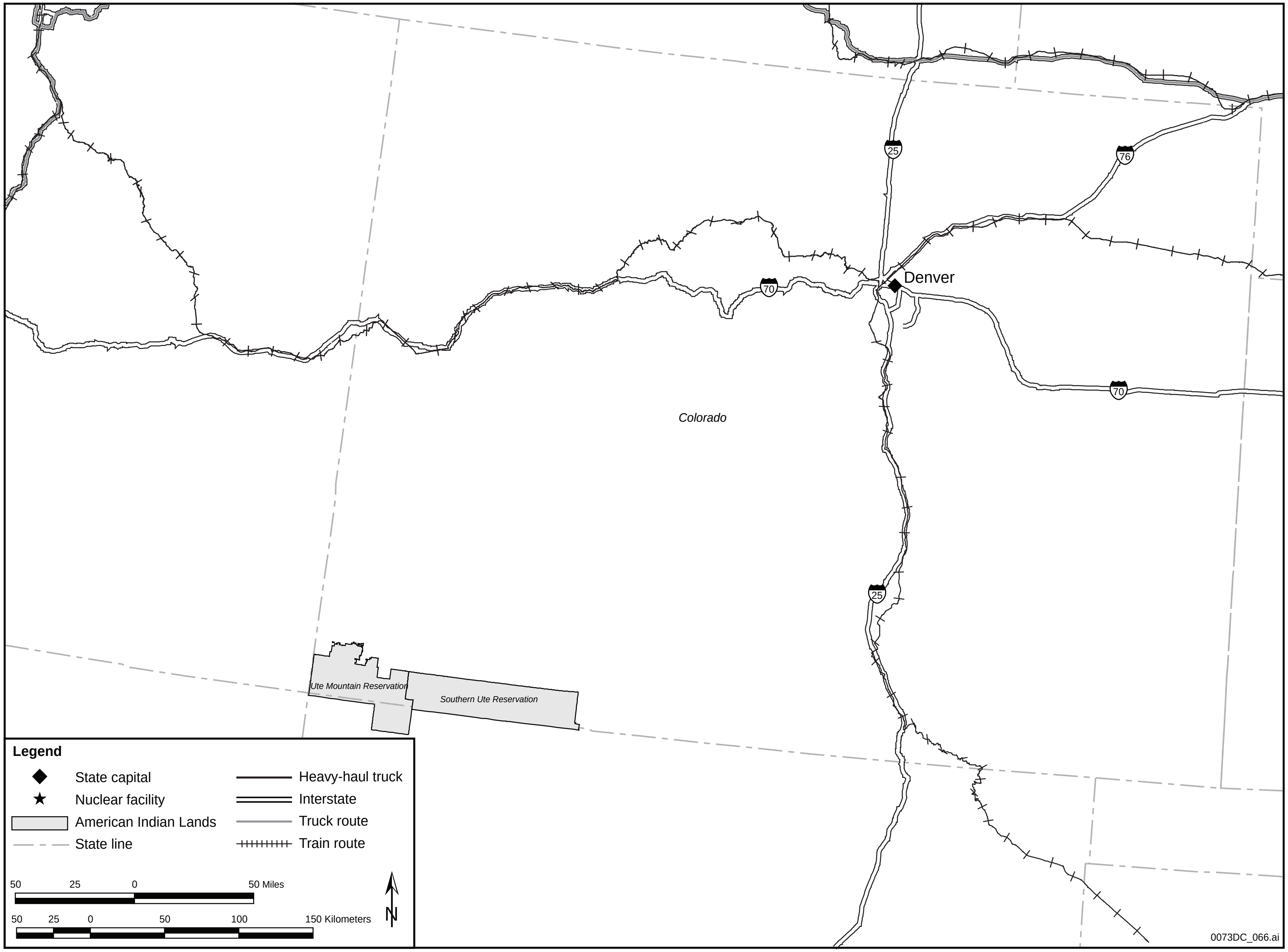

Figure G-7. Representative transportation routes for the State of Colorado.

Table G-27. Estimated transportation impacts for the State of Connecticut.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	216	1.5	19	9.2×10^{-4}	0.012	0.0017	0.0073	4.4×10^{-6}	0.0015	0.016
Truck	344	3.6	3.7	0.0022	0.0022	0.0018	0.0030	1.8×10^{-6}	0.0036	0.0098
Total	560	5.2	23	0.0031	0.014	0.0035	0.010	6.2×10^{-6}	0.0050	0.025
Mina										
Rail	216	1.5	19	9.2×10^{-4}	0.012	0.0017	0.0073	4.4×10^{-6}	0.0015	0.016
Truck	344	3.6	3.7	0.0022	0.0022	0.0018	0.0030	1.8×10^{-6}	0.0036	0.0098
Total	560	5.2	23	0.0031	0.014	0.0035	0.010	6.2×10^{-6}	0.0050	0.025

a. Totals might differ from sums of values due to rounding.

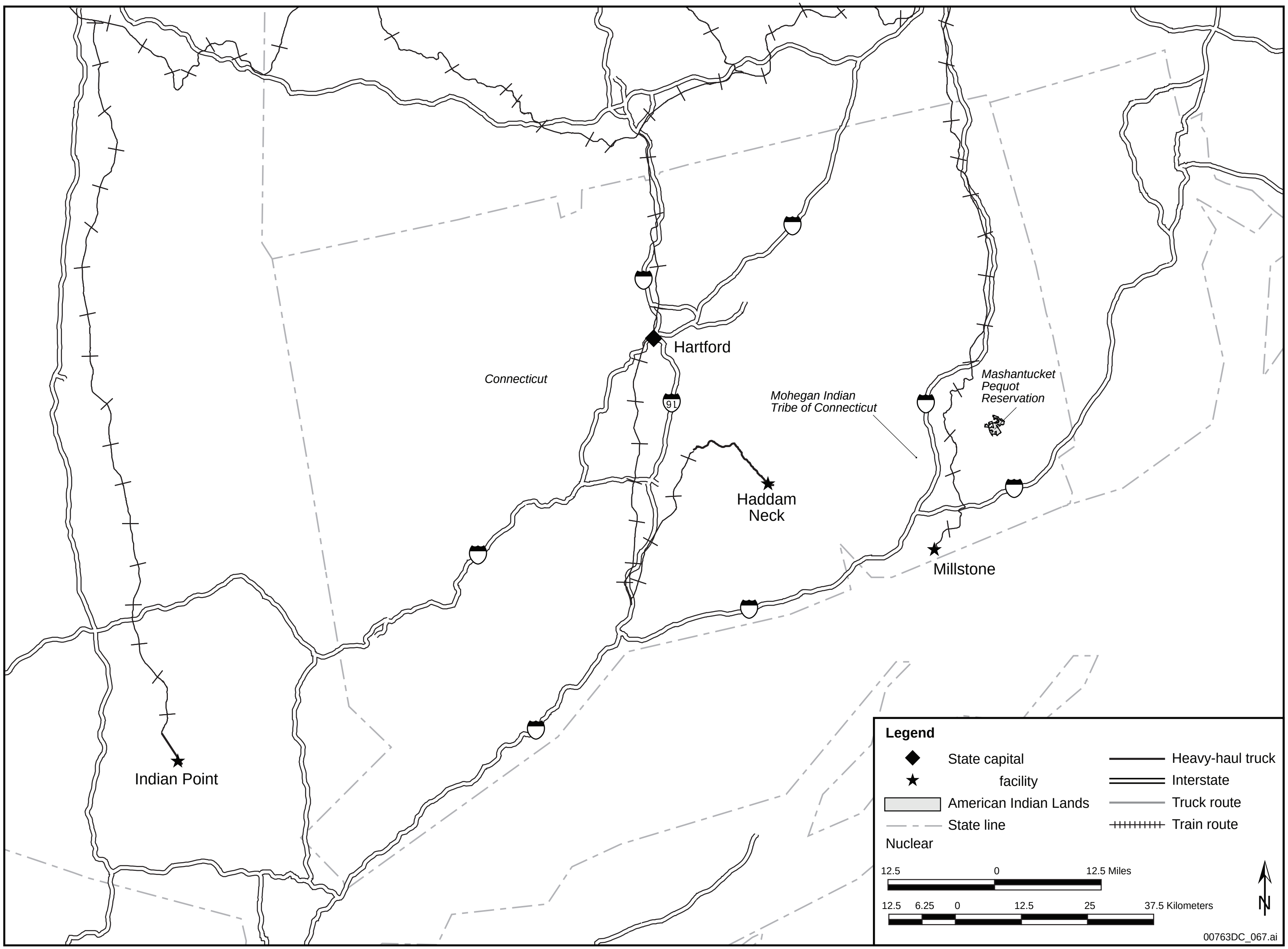

Figure G-8. Representative transportation routes for the State of Connecticut.

Table G-28. Estimated transportation impacts for the District of Columbia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030
Mina										
Rail	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	1.2	0.89	7.0×10^{-4}	5.3×10^{-4}	0.0014	0.0052	3.1×10^{-6}	3.5×10^{-4}	0.0030

a. Totals might differ from sums of values due to rounding.

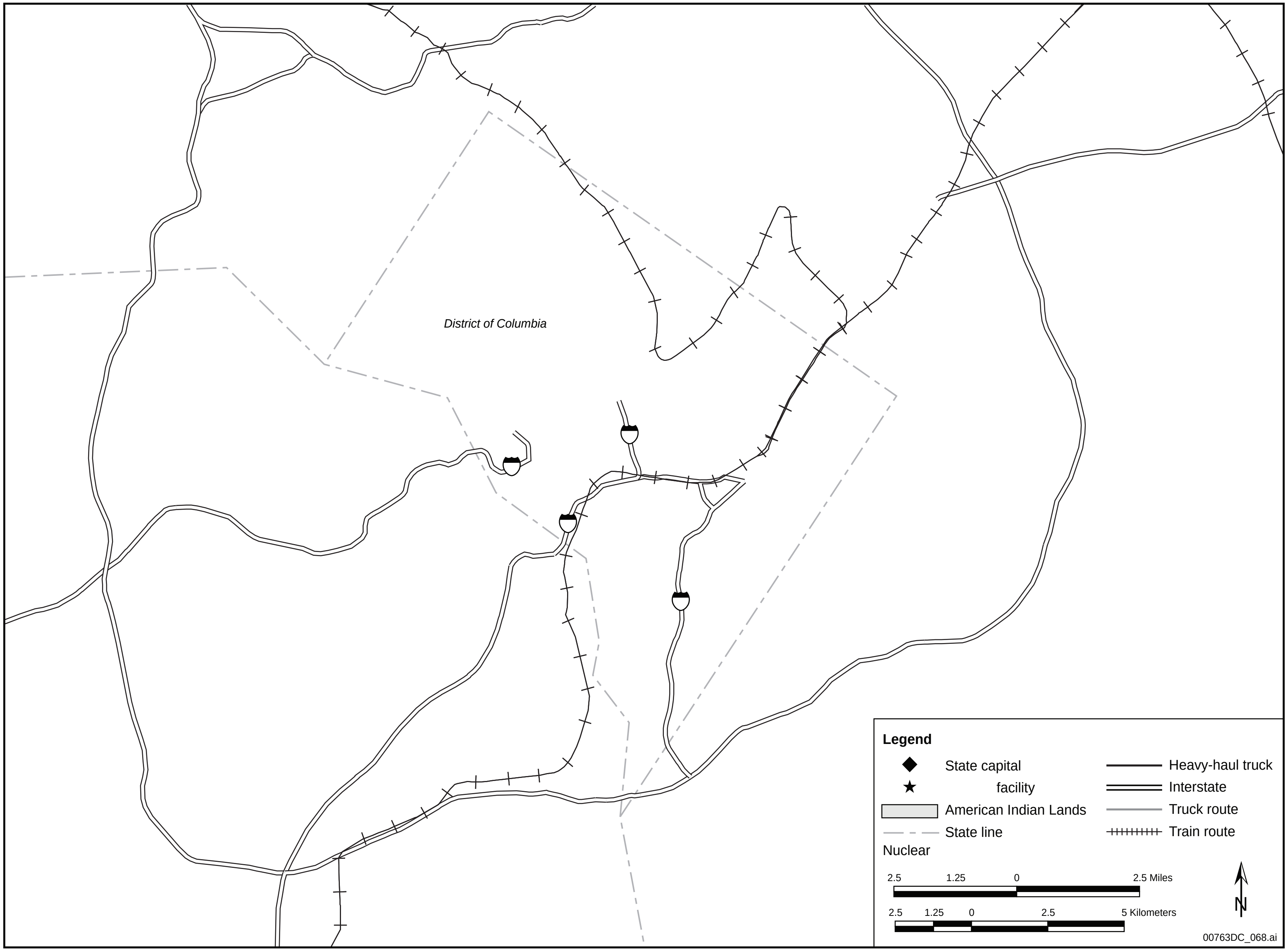

Figure G-9. Representative transportation routes for the District of Columbia.

Table G-29. Estimated transportation impacts for the State of Florida.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	138	13	31	0.0078	0.019	0.013	0.047	2.8×10^{-5}	0.0039	0.043
Truck	857	47	100	0.028	0.060	0.032	0.0040	2.4×10^{-6}	0.040	0.16
Total	995	60	130	0.036	0.079	0.044	0.051	3.1×10^{-5}	0.044	0.20
Mina										
Rail	138	13	31	0.0078	0.019	0.013	0.047	2.8×10^{-5}	0.0039	0.043
Truck	857	47	100	0.028	0.060	0.032	0.0040	2.4×10^{-6}	0.040	0.16
Total	995	60	130	0.036	0.079	0.044	0.051	3.1×10^{-5}	0.044	0.20

a. Totals might differ from sums of values due to rounding.

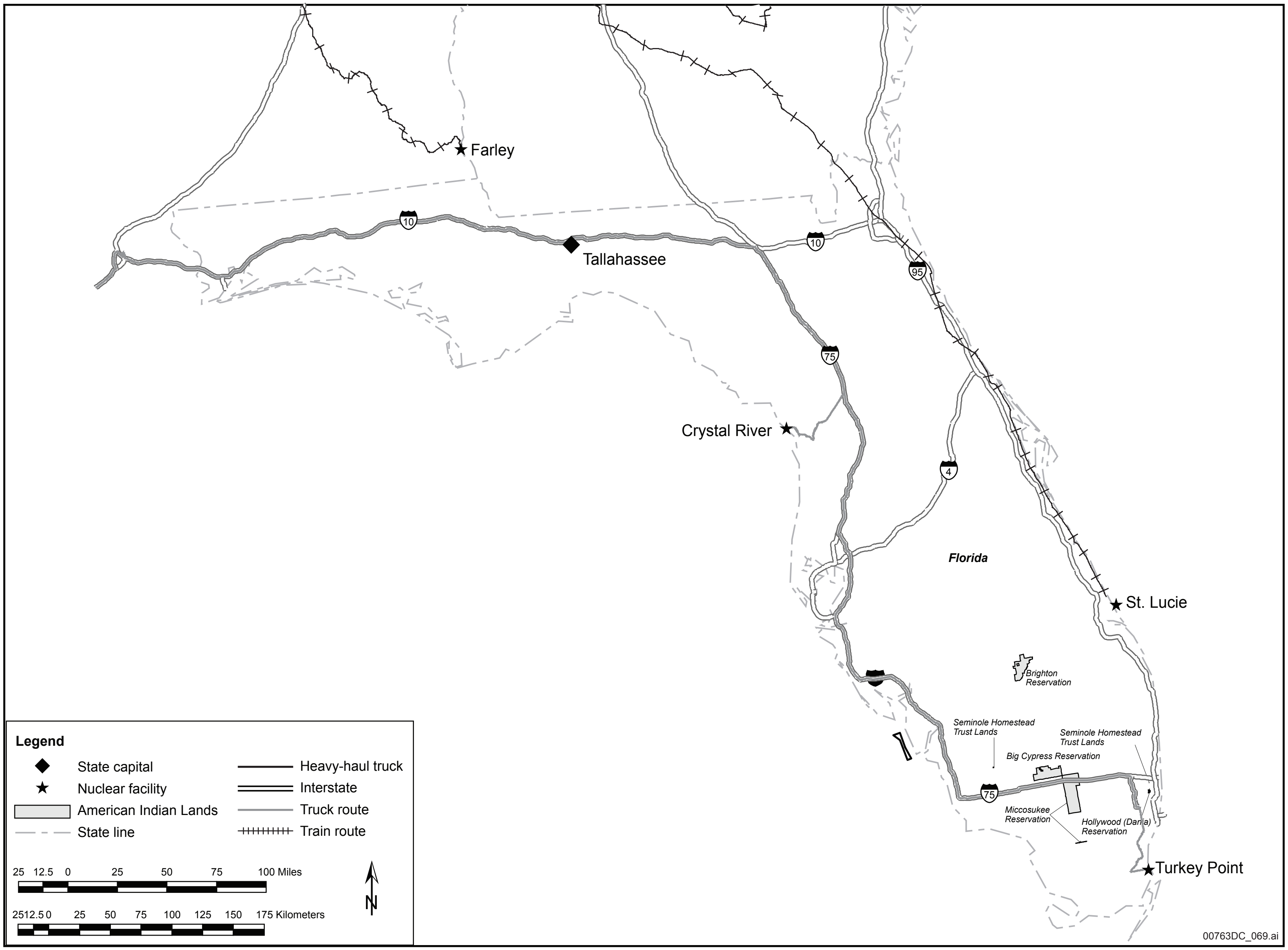

Figure G-10. Representative transportation routes for the State of Florida.

Table G-30. Estimated transportation impacts for the State of Georgia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19
Mina										
Rail	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,672	53	85	0.032	0.051	0.065	0.17	1.0×10^{-4}	0.044	0.19

a. Totals might differ from sums of values due to rounding.

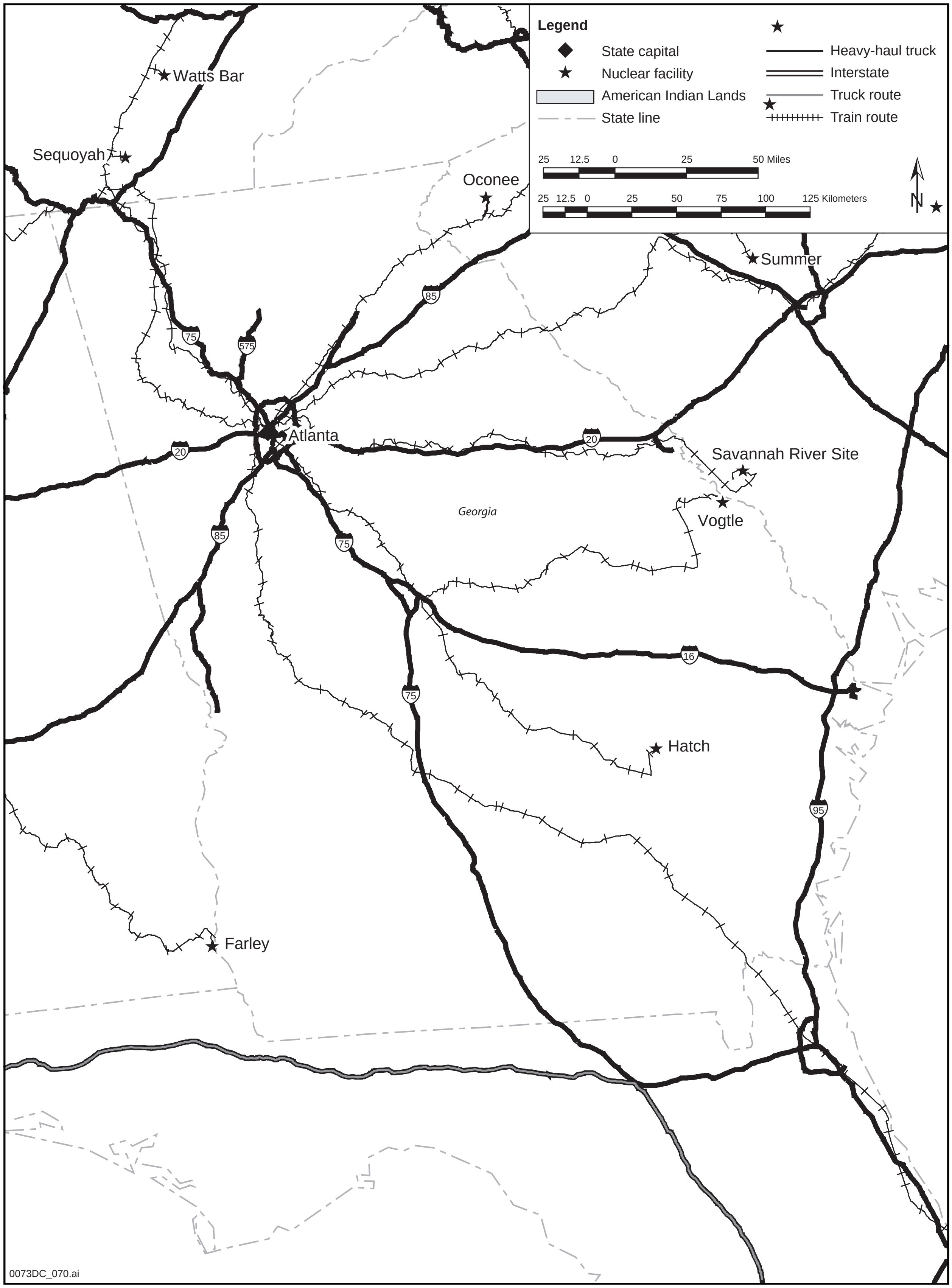

Figure G-11. Representative transportation routes for the State of Georgia.

Table G-31. Estimated transportation impacts for the State of Idaho.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,001	28	310	0.017	0.19	0.021	0.015	9.1×10^{-6}	0.046	0.27
Truck	4	0.046	0.15	2.8×10^{-5}	9.0×10^{-5}	1.7×10^{-5}	9.0×10^{-6}	5.4×10^{-9}	5.0×10^{-5}	1.8×10^{-4}
Total	2,005	28	310	0.017	0.19	0.021	0.015	9.1×10^{-6}	0.046	0.27
Mina										
Rail	694	13	270	0.0080	0.16	0.0043	0.0017	1.0×10^{-6}	0.0077	0.18
Truck	4	0.046	0.15	2.8×10^{-5}	9.0×10^{-5}	1.7×10^{-5}	9.0×10^{-6}	5.4×10^{-9}	5.0×10^{-5}	1.8×10^{-4}
Total	698	13	270	0.0080	0.16	0.0044	0.0017	1.0×10^{-6}	0.0077	0.18

a. Totals might differ from sums of values due to rounding.

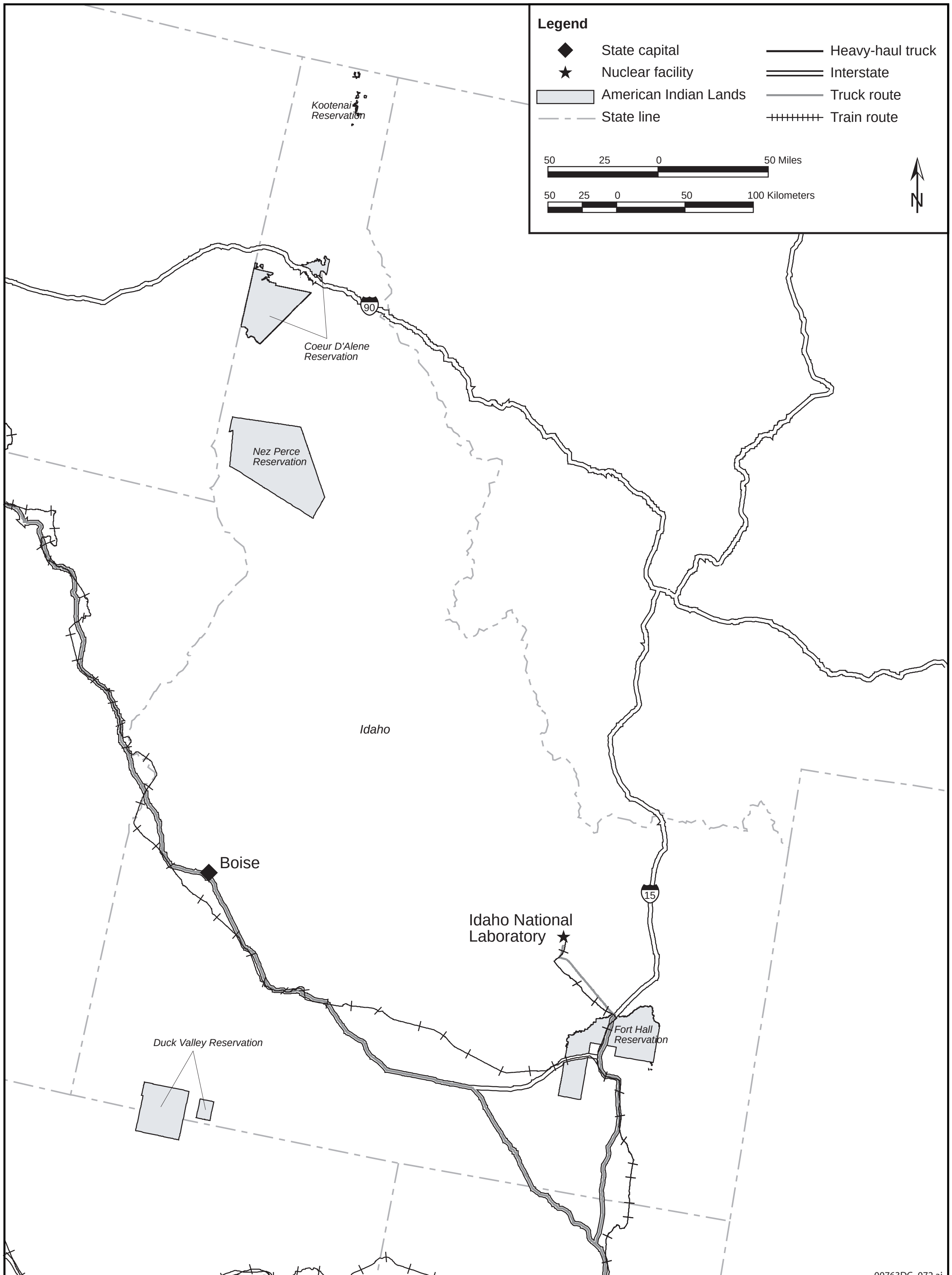

Figure G-12. Representative transportation routes for the State of Idaho.

Table G-32. Estimated transportation impacts for the State of Illinois.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,069	75	200	0.045	0.12	0.094	0.47	2.8×10^{-4}	0.091	0.35
Truck	1,752	15	46	0.0090	0.028	0.0044	0.0020	1.2×10^{-6}	0.021	0.062
Total	7,821	90	250	0.054	0.15	0.099	0.47	2.8×10^{-4}	0.11	0.41
Mina										
Rail	6,069	75	200	0.045	0.12	0.094	0.47	2.8×10^{-4}	0.091	0.35
Truck	1,752	15	46	0.0090	0.028	0.0044	0.0020	1.2×10^{-6}	0.021	0.062
Total	7,821	90	250	0.054	0.15	0.099	0.47	2.8×10^{-4}	0.11	0.41

a. Totals might differ from sums of values due to rounding.

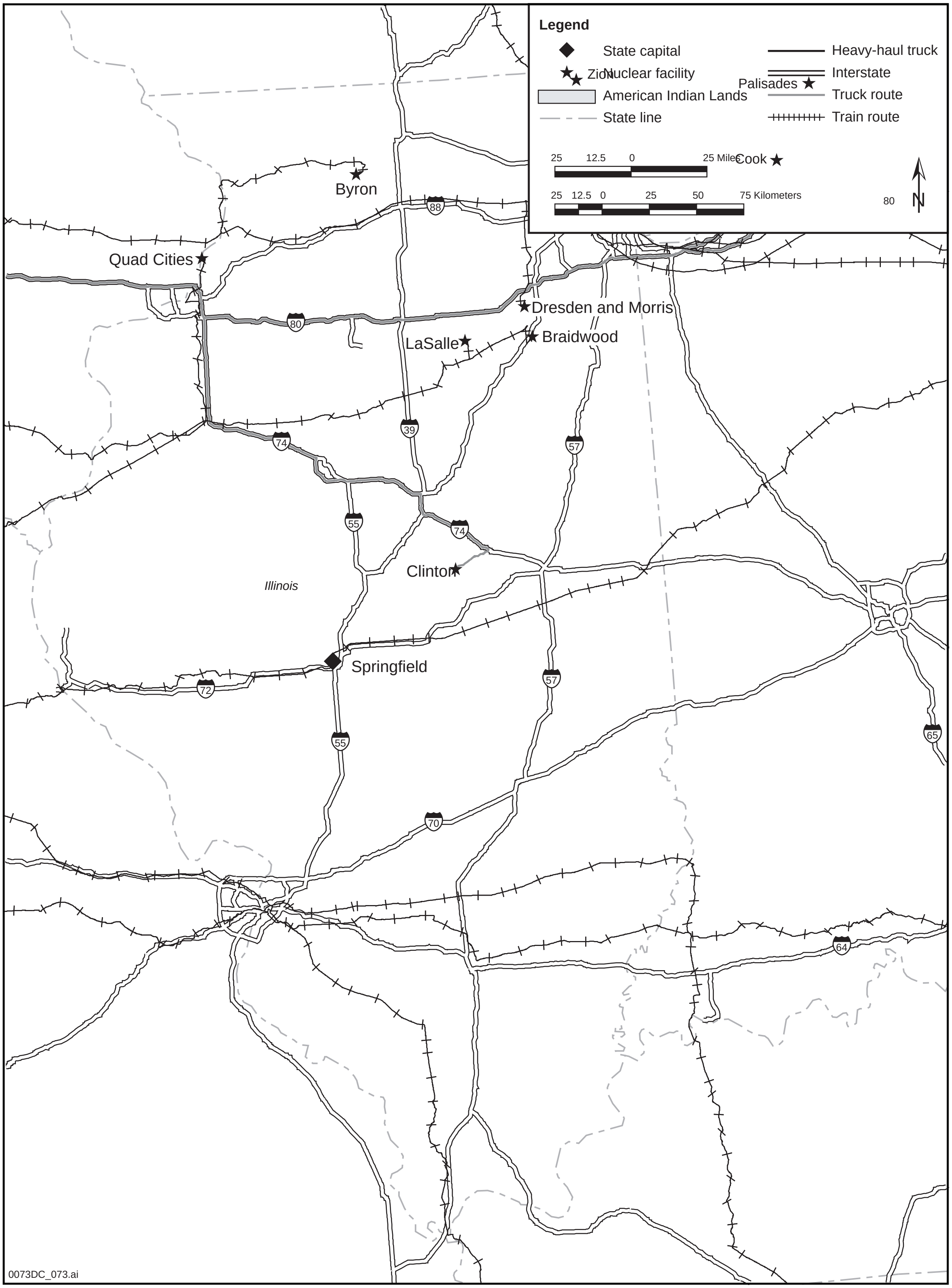

Figure G-13. Representative transportation routes for the State of Illinois.

Table G-33. Estimated transportation impacts for the State of Indiana.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	4,887	27	86	0.016	0.052	0.036	0.18	1.1×10^{-4}	0.055	0.16
Truck	1,425	9.1	15	0.0055	0.0088	0.0035	0.0015	9.0×10^{-7}	0.0089	0.027
Total	6,312	36	100	0.021	0.061	0.039	0.19	1.1×10^{-4}	0.064	0.19
Mina										
Rail	4,887	27	86	0.016	0.052	0.036	0.18	1.1×10^{-4}	0.055	0.16
Truck	1,425	9.1	15	0.0055	0.0088	0.0035	0.0015	9.0×10^{-7}	0.0089	0.027
Total	6,312	36	100	0.021	0.061	0.039	0.19	1.1×10^{-4}	0.064	0.19

a. Totals might differ from sums of values due to rounding.

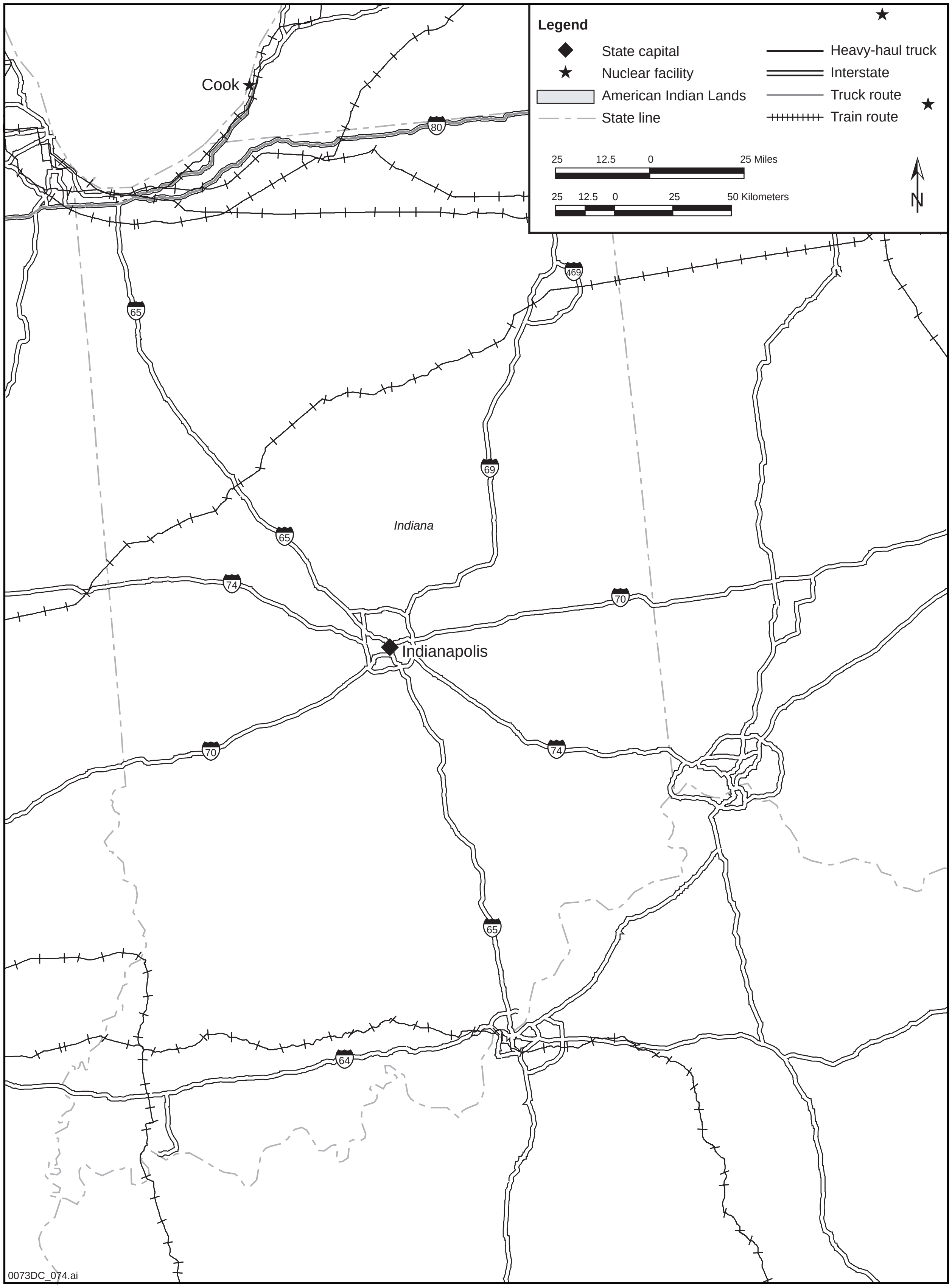

Figure G-14. Representative transportation routes for the State of Indiana.

Table G-34. Estimated transportation impacts for the State of Iowa.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	3,066	13	150	0.0079	0.089	0.020	0.19	1.2×10^{-4}	0.096	0.21
Truck	1,789	22	59	0.013	0.035	0.0037	0.0011	6.5×10^{-7}	0.044	0.096
Total	4,855	35	210	0.021	0.12	0.023	0.19	1.2×10^{-4}	0.14	0.31
Mina										
Rail	3,066	13	150	0.0079	0.089	0.020	0.19	1.2×10^{-4}	0.096	0.21
Truck	1,789	22	59	0.013	0.035	0.0037	0.0011	6.5×10^{-7}	0.044	0.096
Total	4,855	35	210	0.021	0.12	0.023	0.19	1.2×10^{-4}	0.14	0.31

a. Totals might differ from sums of values due to rounding.

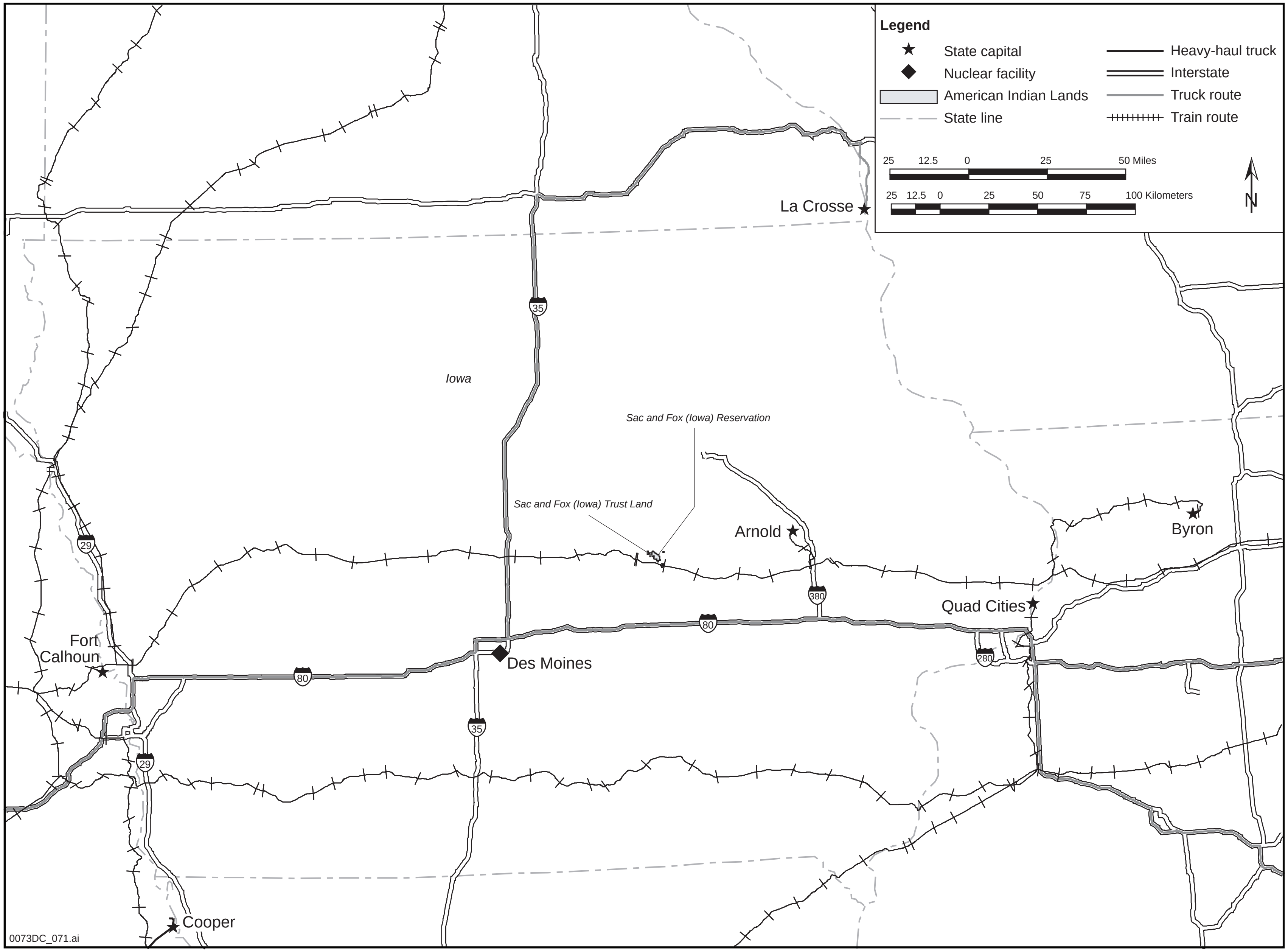

Figure G-15. Representative transportation routes for the State of Iowa.

Table G-35. Estimated transportation impacts for the State of Kansas.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13
Mina										
Rail	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	8.7	90	0.0052	0.054	0.012	0.066	3.9×10^{-5}	0.061	0.13

a. Totals might differ from sums of values due to rounding.

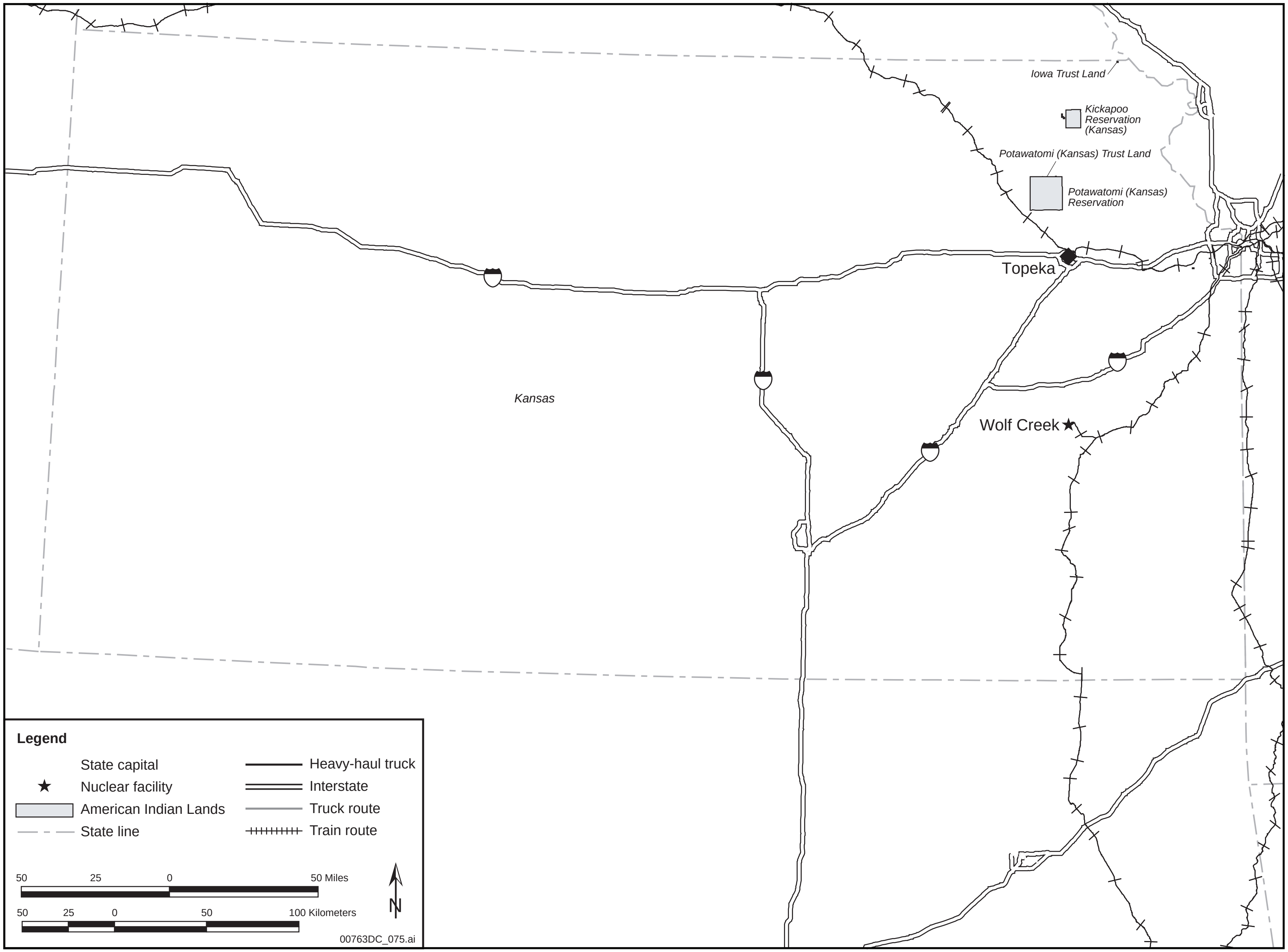

Figure G-16. Representative transportation routes for the State of Kansas.

Table G-36. Estimated transportation impacts for the Commonwealth of Kentucky.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090
Mina										
Rail	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	14	50	0.0086	0.030	0.020	0.077	4.6×10^{-5}	0.032	0.090

a. Totals might differ from sums of values due to rounding.

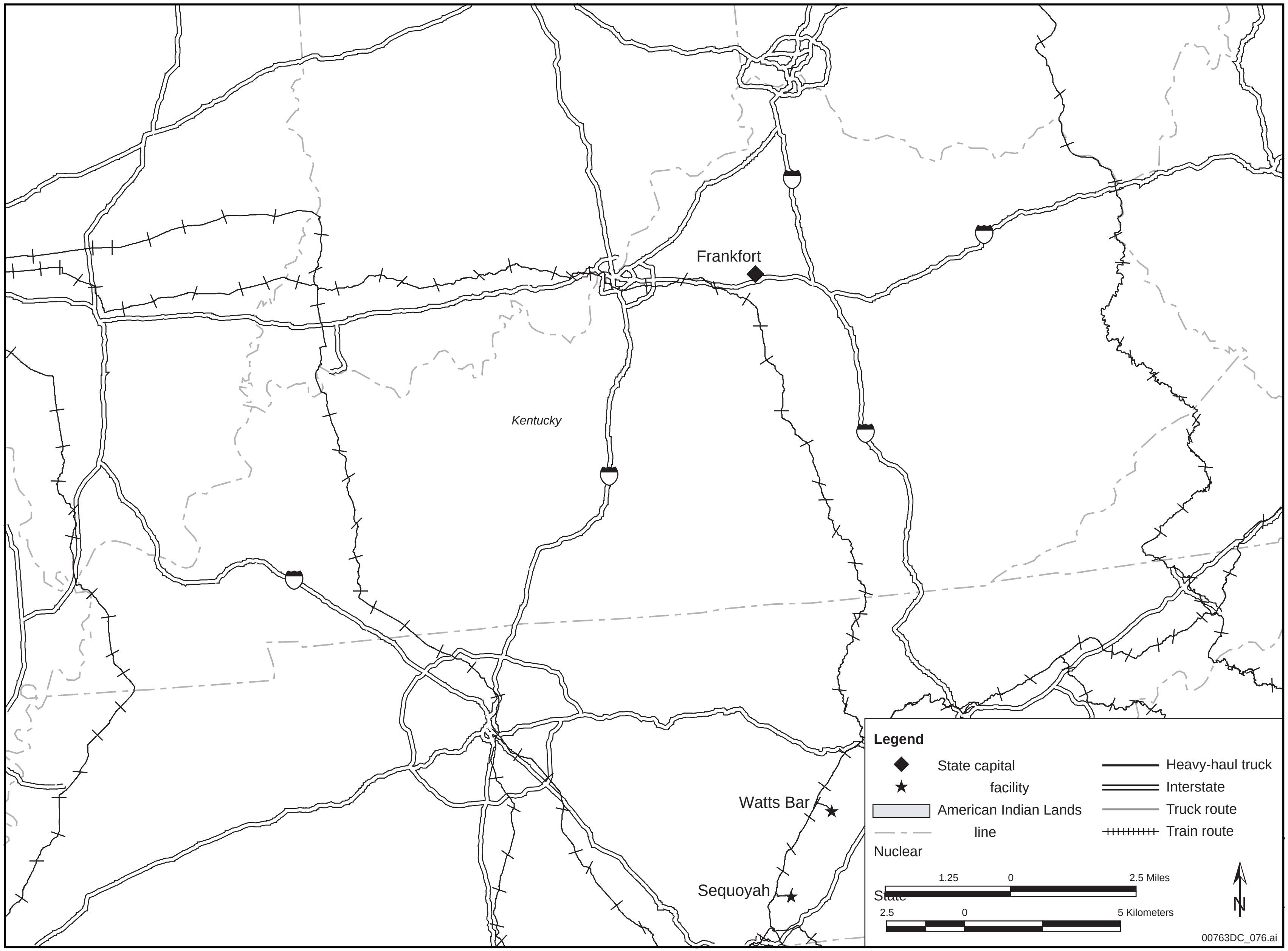

Figure G-17. Representative transportation routes for the Commonwealth of Kentucky.

Table G-37. Estimated transportation impacts for the State of Louisiana.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	233	1.3	14	7.8×10^{-4}	0.0082	0.0019	0.0098	5.9×10^{-6}	0.0043	0.015
Truck	857	17	35	0.010	0.021	0.0054	0.0022	1.3×10^{-6}	0.025	0.062
Total	1,090	19	48	0.011	0.029	0.0073	0.012	7.2×10^{-6}	0.029	0.077
Mina										
Rail	233	1.3	14	7.8×10^{-4}	0.0082	0.0019	0.0098	5.9×10^{-6}	0.0043	0.015
Truck	857	17	35	0.010	0.021	0.0054	0.0022	1.3×10^{-6}	0.025	0.062
Total	1,090	19	48	0.011	0.029	0.0073	0.012	7.2×10^{-6}	0.029	0.077

a. Totals might differ from sums of values due to rounding.

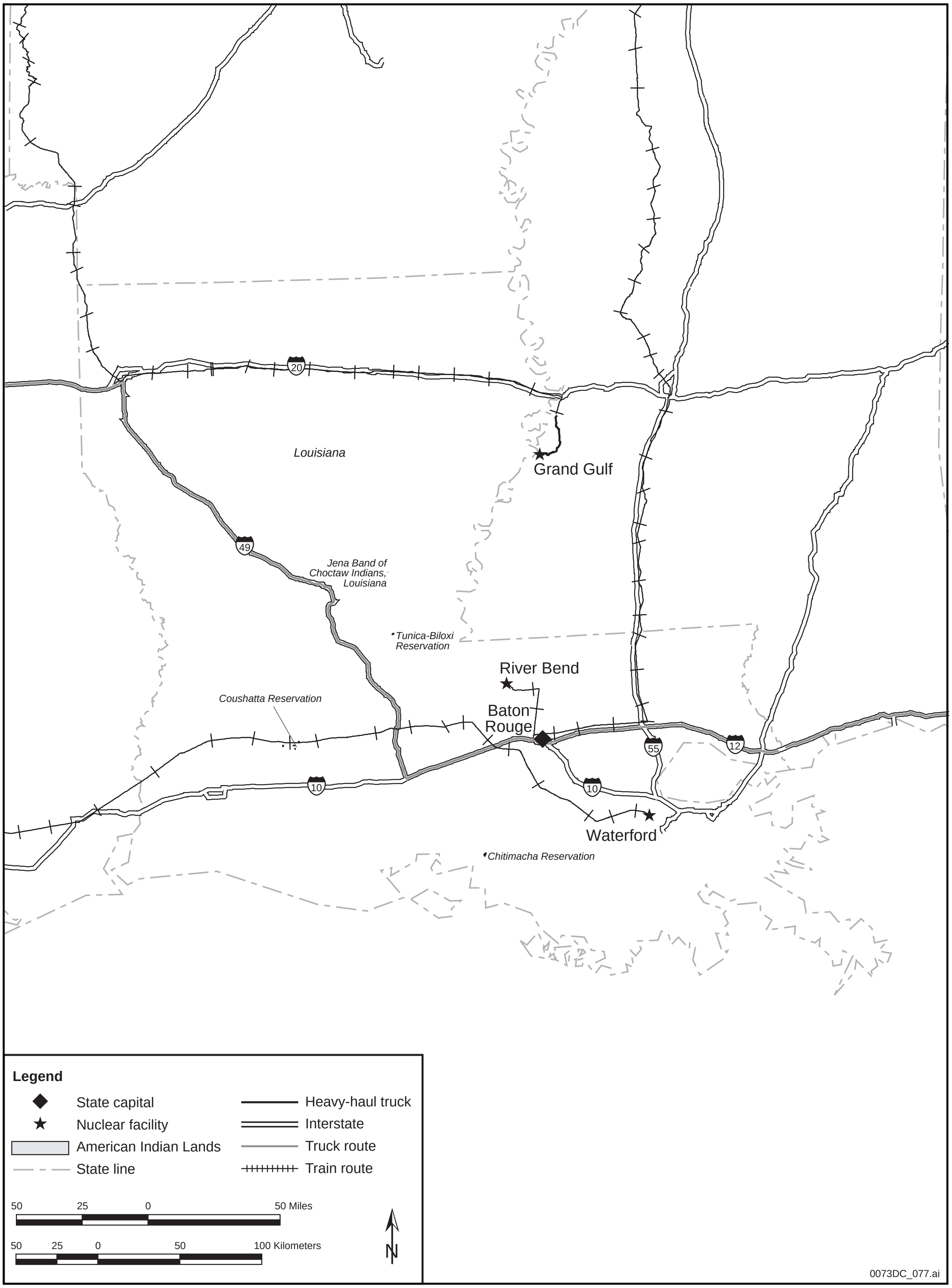

Figure G-18. Representative transportation routes for the State of Louisiana.

Table G-38. Estimated transportation impacts for the State of Maine.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037
Truck	0	0	0	0	0	0	0	0	0	0
Total	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037
Mina										
Rail	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037
Truck	0	0	0	0	0	0	0	0	0	0
Total	60	0.38	4.1	2.3×10^{-4}	0.0025	5.0×10^{-4}	0.0021	1.3×10^{-6}	5.3×10^{-4}	0.0037

a. Totals might differ from sums of values due to rounding.

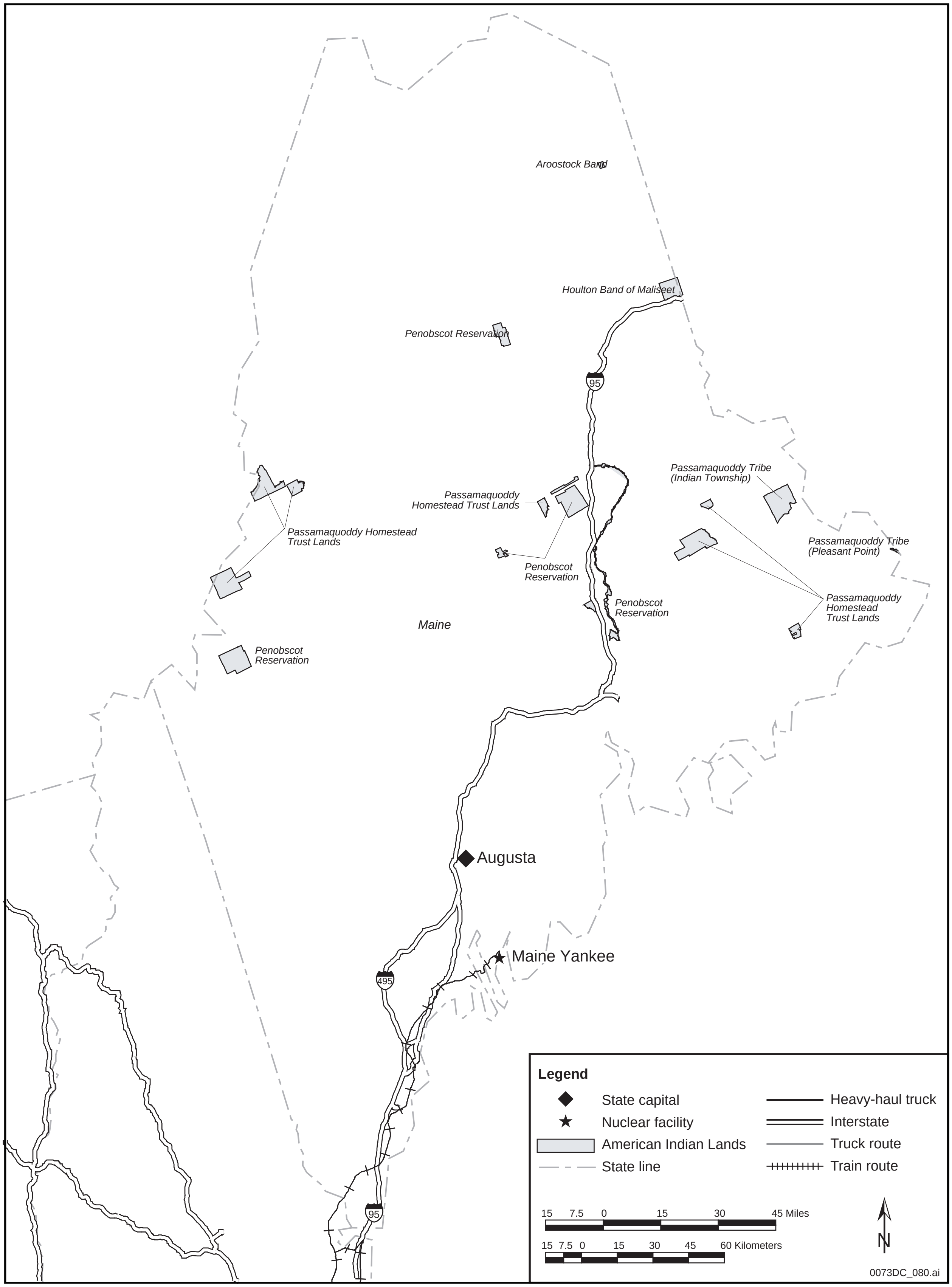

Figure G-19. Representative transportation routes for the State of Maine.

Table G-39. Estimated transportation impacts for the State of Maryland.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034
Mina										
Rail	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	7.9	30	0.0047	0.018	0.0075	0.029	1.8×10^{-5}	0.0039	0.034

a. Totals might differ from sums of values due to rounding.

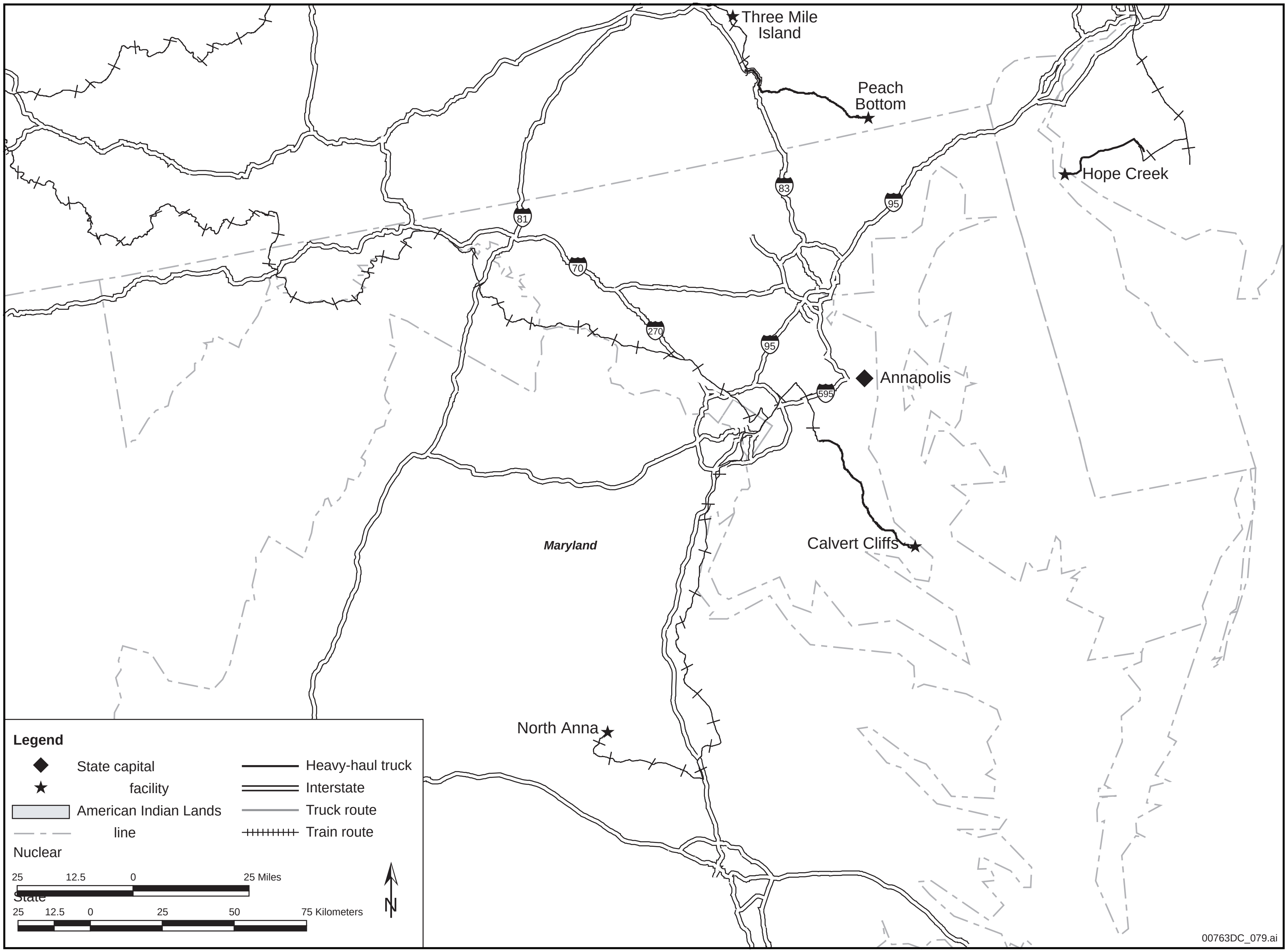

Figure G-20. Representative transportation routes for the State of Maryland.

Table G-40. Estimated transportation impacts for the Commonwealth of Massachusetts.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	415	4.8	12	0.0029	0.0071	0.0064	0.028	1.7×10^{-5}	0.0053	0.022
Truck	344	2.5	19	0.0015	0.012	8.9×10^{-4}	1.4×10^{-4}	8.4×10^{-8}	0.0013	0.015
Total	759	7.3	31	0.0044	0.019	0.0072	0.028	1.7×10^{-5}	0.0066	0.037
Mina										
Rail	415	4.8	12	0.0029	0.0071	0.0064	0.028	1.7×10^{-5}	0.0053	0.022
Truck	344	2.5	19	0.0015	0.012	8.9×10^{-4}	1.4×10^{-4}	8.4×10^{-8}	0.0013	0.015
Total	759	7.3	31	0.0044	0.019	0.0072	0.028	1.7×10^{-5}	0.0066	0.037

a. Totals might differ from sums of values due to rounding.

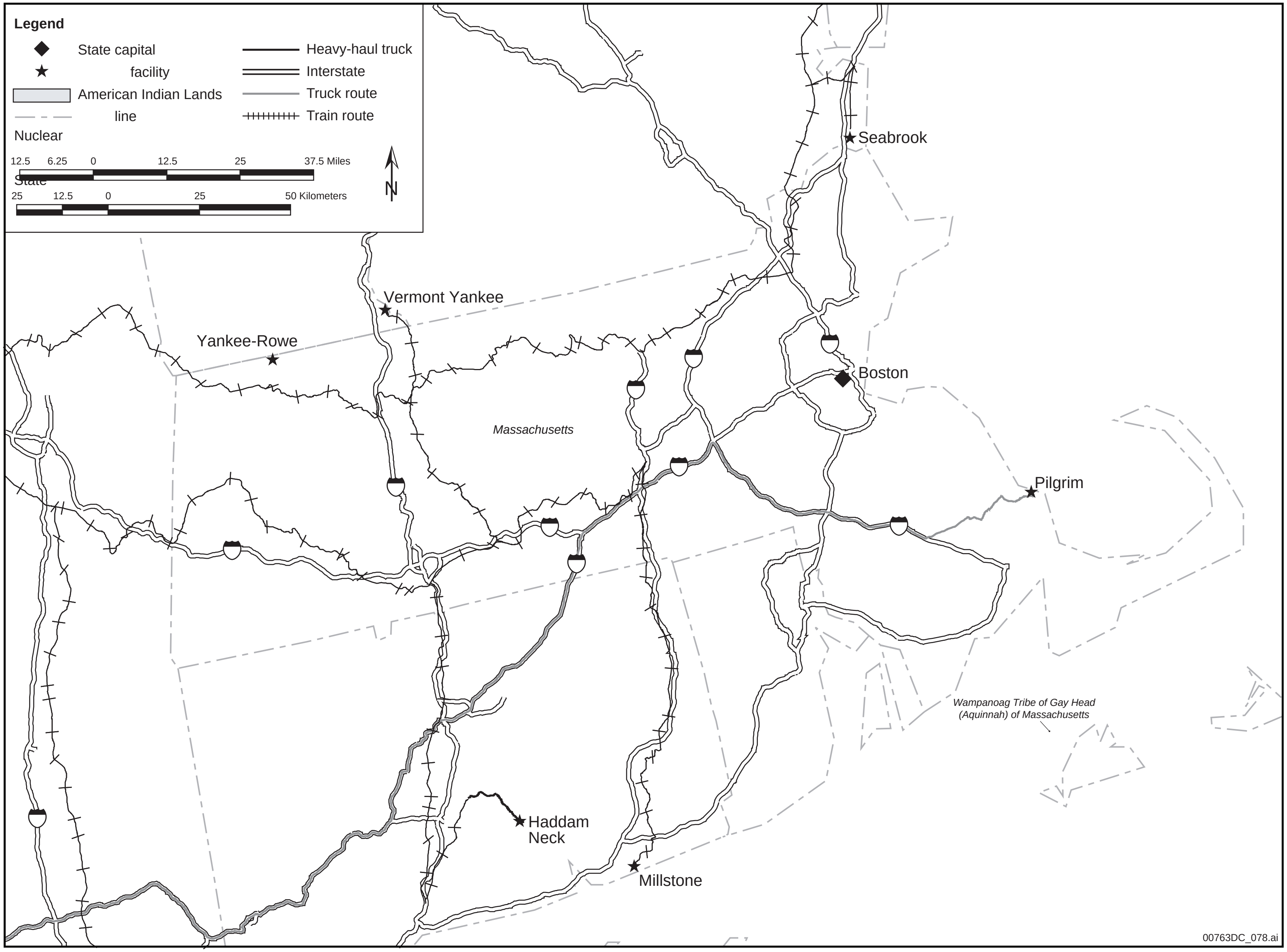

Figure G-21. Representative transportation routes for the Commonwealth of Massachusetts.

Table G-41. Estimated transportation impacts for the State of Michigan.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	132	2.3	20	0.0014	0.012	0.0023	0.013	7.8×10^{-6}	0.0025	0.018
Truck	768	0.66	37	4.0×10^{-4}	0.022	1.4×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0012	0.024
Total	900	2.9	57	0.0018	0.034	0.0024	0.013	7.9×10^{-6}	0.0038	0.042
Mina										
Rail	132	2.3	20	0.0014	0.012	0.0023	0.013	7.8×10^{-6}	0.0025	0.018
Truck	768	0.66	37	4.0×10^{-4}	0.022	1.4×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0012	0.024
Total	900	2.9	57	0.0018	0.034	0.0024	0.013	7.9×10^{-6}	0.0038	0.042

a. Totals might differ from sums of values due to rounding.

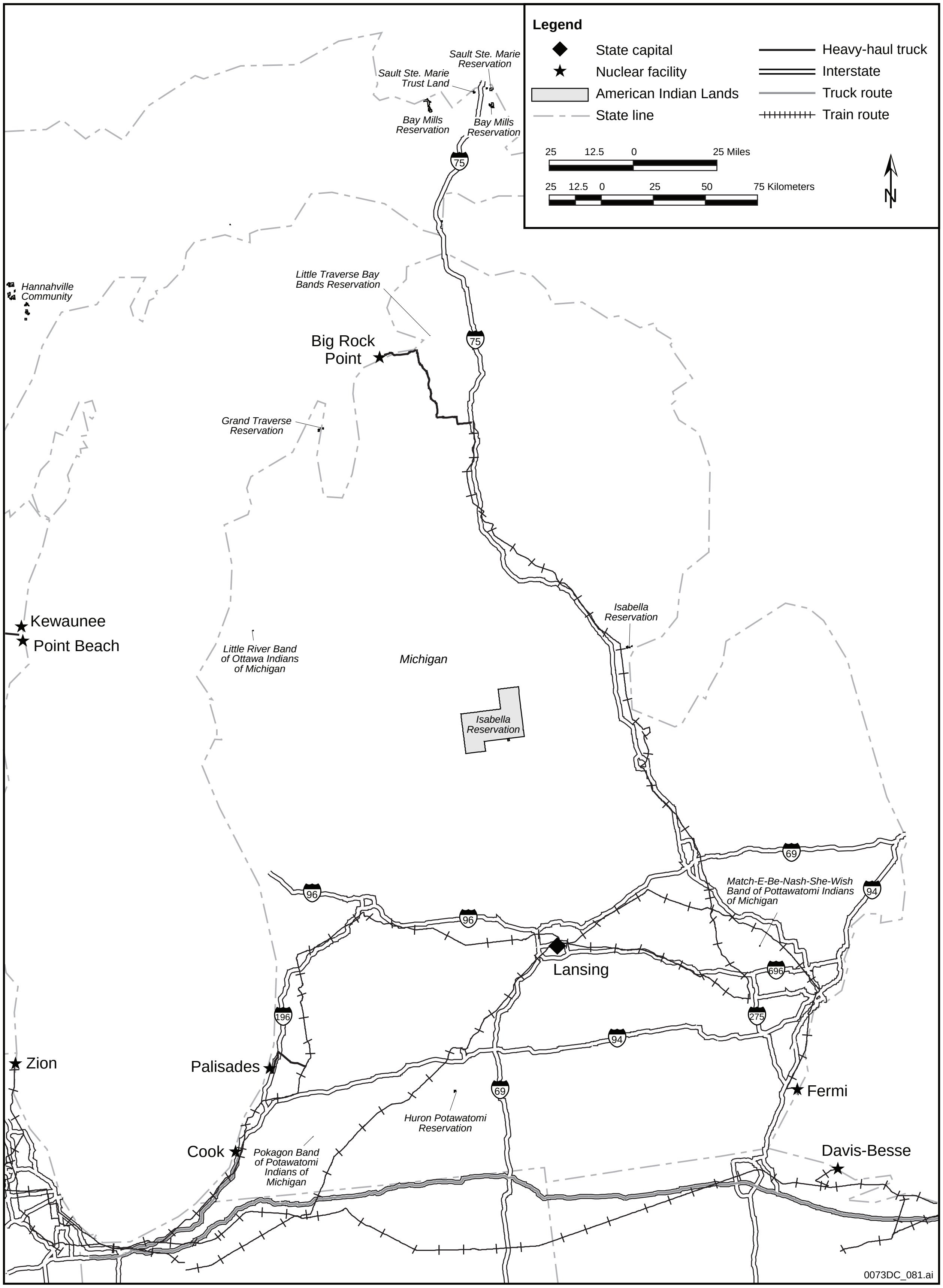

Figure G-22. Representative transportation routes for the State of Michigan.

Table G-42. Estimated transportation impacts for the State of Minnesota.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	153	1.5	14	9.0×10^{-4}	0.0083	0.0021	0.011	6.3×10^{-6}	0.0036	0.015
Truck	37	0.18	0.51	1.1×10^{-4}	3.1×10^{-4}	3.3×10^{-5}	1.2×10^{-5}	7.0×10^{-9}	2.3×10^{-4}	6.7×10^{-4}
Total	190	1.7	14	0.0010	0.0086	0.0021	0.011	6.3×10^{-6}	0.0038	0.016
Mina										
Rail	153	1.5	14	9.0×10^{-4}	0.0083	0.0021	0.011	6.3×10^{-6}	0.0036	0.015
Truck	37	0.18	0.51	1.1×10^{-4}	3.1×10^{-4}	3.3×10^{-5}	1.2×10^{-5}	7.0×10^{-9}	2.3×10^{-4}	6.7×10^{-4}
Total	190	1.7	14	0.0010	0.0086	0.0021	0.011	6.3×10^{-6}	0.0038	0.016

a. Totals might differ from sums of values due to rounding.

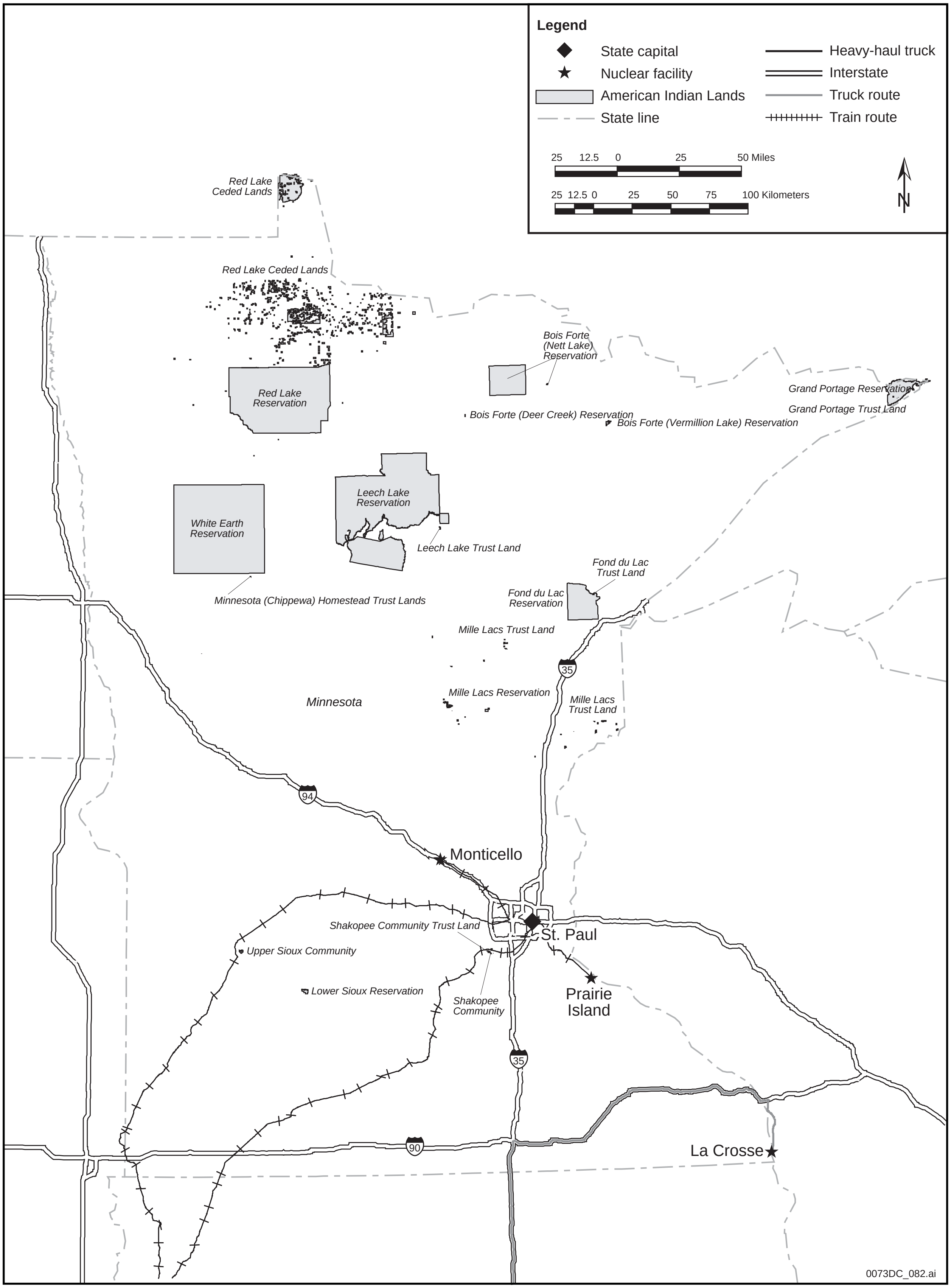

Figure G-23. Representative transportation routes for the State of Minnesota.

Table G-43. Estimated transportation impacts for the State of Mississippi.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	170	1.2	22	7.0×10^{-4}	0.013	7.4×10^{-4}	0.0042	2.5×10^{-6}	0.0026	0.017
Truck	857	3.3	7.2	0.0020	0.0043	8.5×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0030	0.010
Total	1,027	4.5	29	0.0027	0.017	0.0016	0.0043	2.6×10^{-6}	0.0055	0.027
Mina										
Rail	170	1.2	22	7.0×10^{-4}	0.013	7.4×10^{-4}	0.0042	2.5×10^{-6}	0.0026	0.017
Truck	857	3.3	7.2	0.0020	0.0043	8.5×10^{-4}	7.5×10^{-5}	4.5×10^{-8}	0.0030	0.010
Total	1,027	4.5	29	0.0027	0.017	0.0016	0.0043	2.6×10^{-6}	0.0055	0.027

a. Totals might differ from sums of values due to rounding.

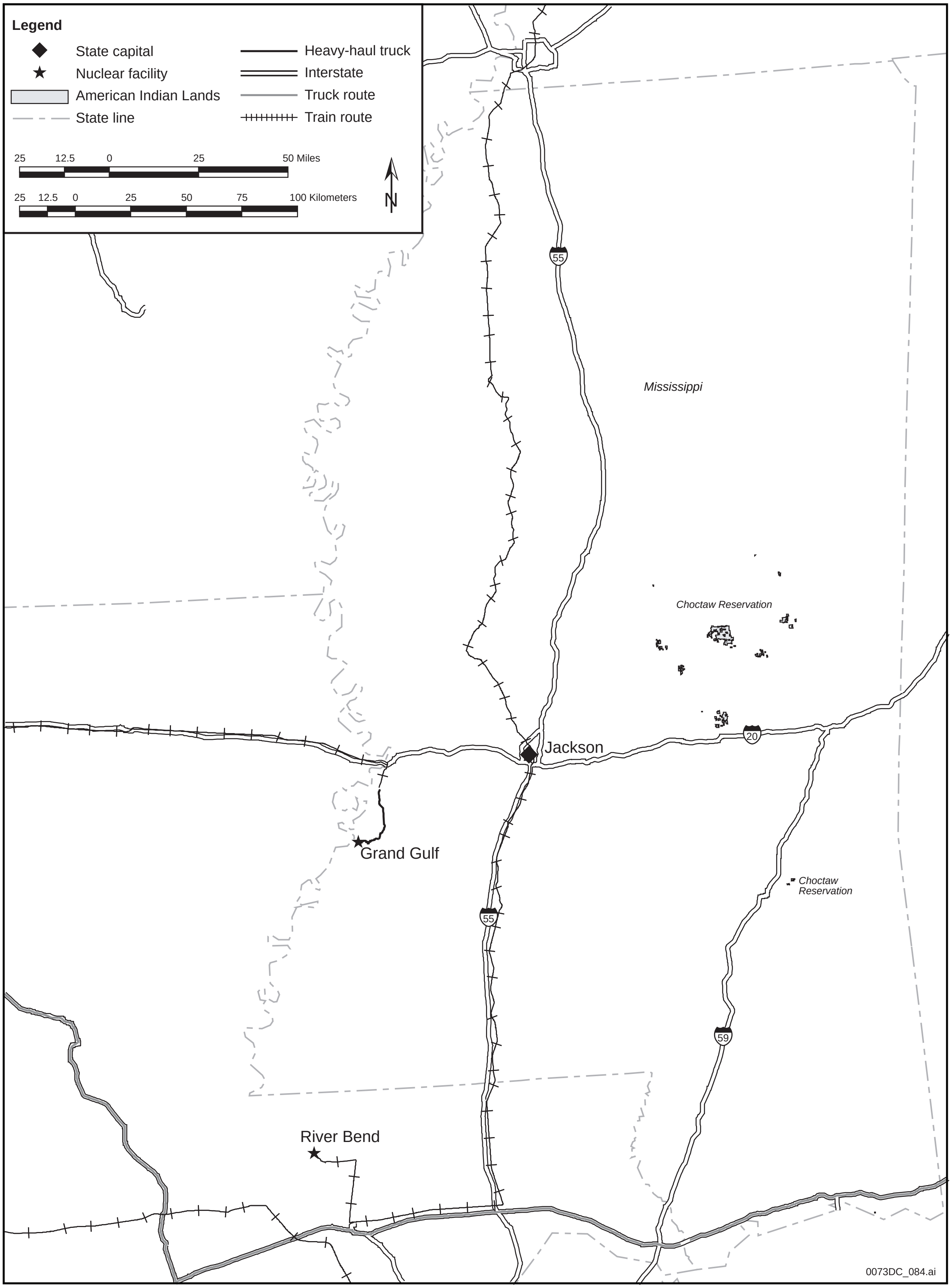

Figure G-24. Representative transportation routes for the State of Mississippi.

Table G-44. Estimated transportation impacts for the State of Missouri.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24
Mina										
Rail	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24
Truck	0	0	0	0	0	0	0	0	0	0
Total	3,574	41	140	0.024	0.083	0.052	0.19	1.2×10^{-4}	0.082	0.24

a. Totals might differ from sums of values due to rounding.

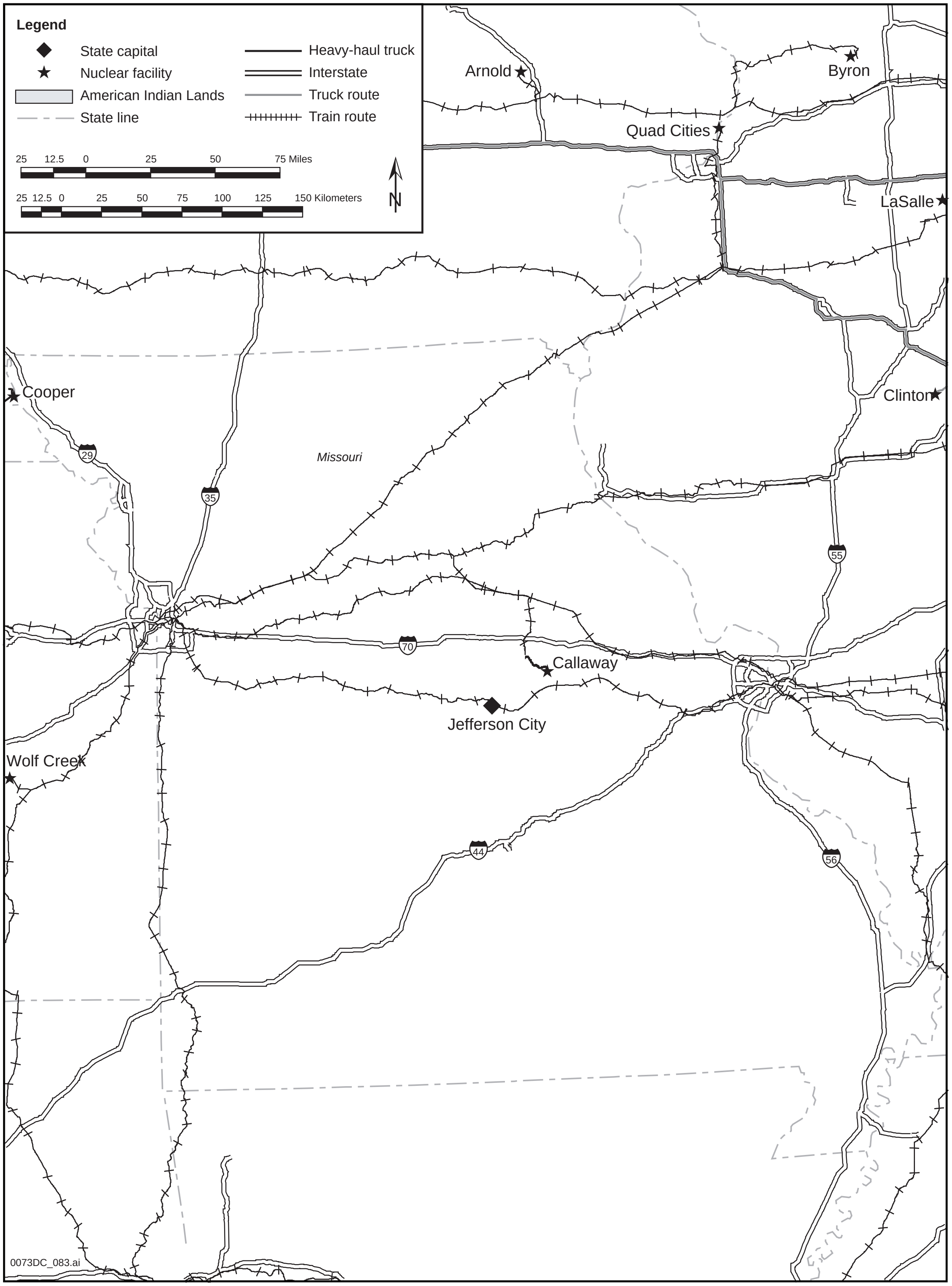

Figure G-25. Representative transportation routes for the State of Missouri.

Table G-45. Estimated transportation impacts for the State of Nebraska.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,739	37	400	0.022	0.24	0.052	0.35	2.1×10^{-4}	0.27	0.59
Truck	1,789	30	88	0.018	0.053	0.0042	0.0030	1.8×10^{-6}	0.083	0.16
Total	8,528	67	490	0.040	0.30	0.056	0.35	2.1×10^{-4}	0.35	0.74
Mina										
Rail	6,739	37	400	0.022	0.24	0.052	0.35	2.1×10^{-4}	0.27	0.59
Truck	1,789	30	88	0.018	0.053	0.0042	0.0030	1.8×10^{-6}	0.083	0.16
Total	8,528	67	490	0.040	0.30	0.056	0.35	2.1×10^{-4}	0.35	0.74

a. Totals might differ from sums of values due to rounding.

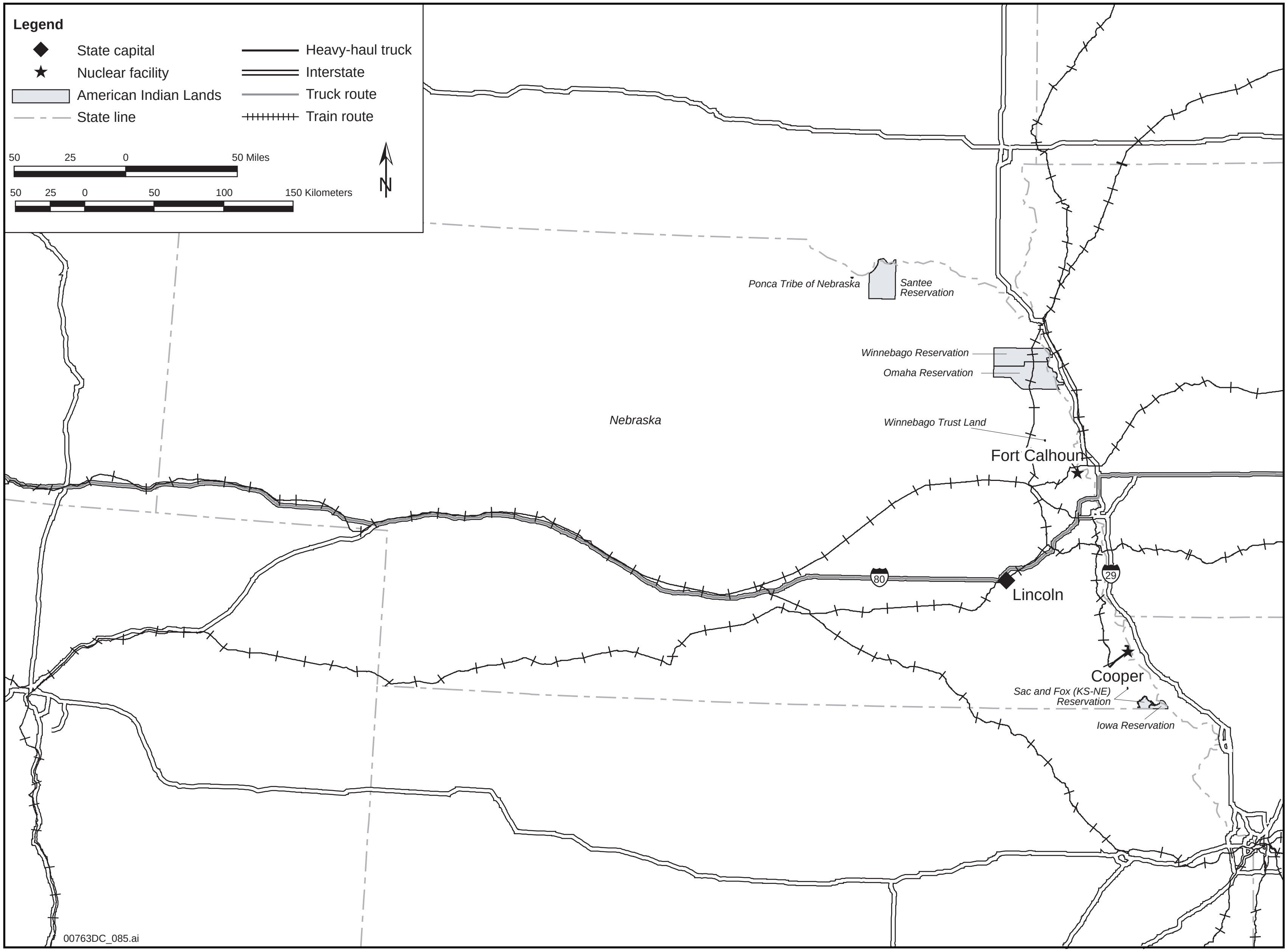

Figure G-26. Representative transportation routes for the State of Nebraska.

Table G-46. Estimated transportation impacts for the State of Nevada.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	9,495	16	680	0.0096	0.41	0.020	0.075	4.5×10^{-5}	0.34	0.78
Truck	2,650	21	95	0.012	0.057	0.0046	0.0032	1.9×10^{-6}	0.050	0.12
Total	12,145	37	770	0.022	0.46	0.024	0.078	4.7×10^{-5}	0.39	0.90
Mina										
Rail	9,495	30	1,500	0.018	0.88	0.037	0.10	6.3×10^{-5}	0.58	1.5
Truck	2,650	21	95	0.012	0.057	0.0046	0.0032	1.9×10^{-6}	0.050	0.12
Total	12,145	50	1,600	0.030	0.94	0.042	0.11	6.5×10^{-5}	0.63	1.6

a. Totals might differ from sums of values due to rounding.

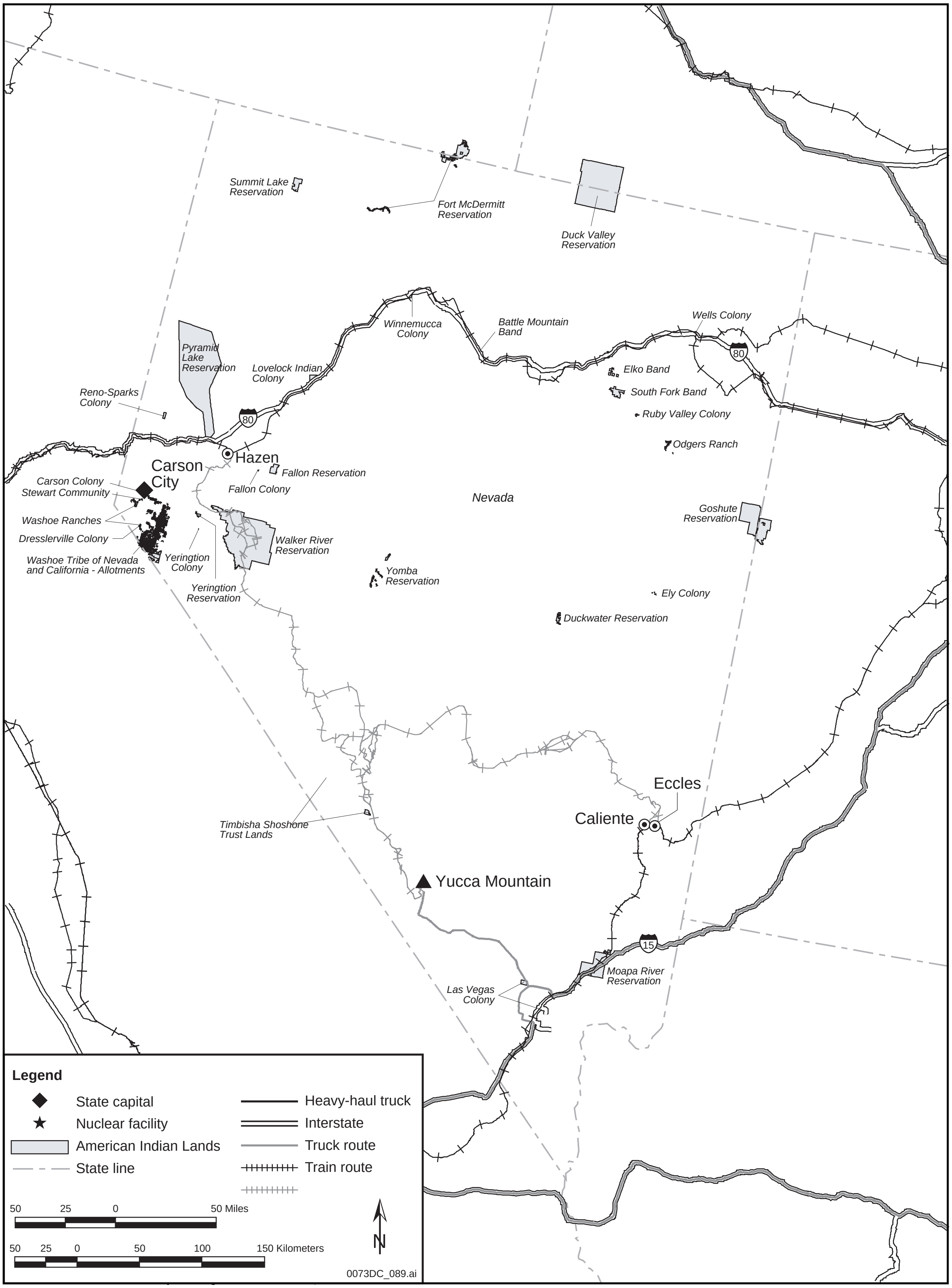

Figure G-27. Representative transportation routes for the State of Nevada.

Table G-47. Estimated transportation impacts for the State of New Hampshire.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032
Truck	0	0	0	0	0	0	0	0	0	0
Total	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032
Mina										
Rail	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032
Truck	0	0	0	0	0	0	0	0	0	0
Total	110	0.41	3.4	2.5×10^{-4}	0.0020	5.6×10^{-4}	0.0023	1.4×10^{-6}	4.0×10^{-4}	0.0032

a. Totals might differ from sums of values due to rounding.

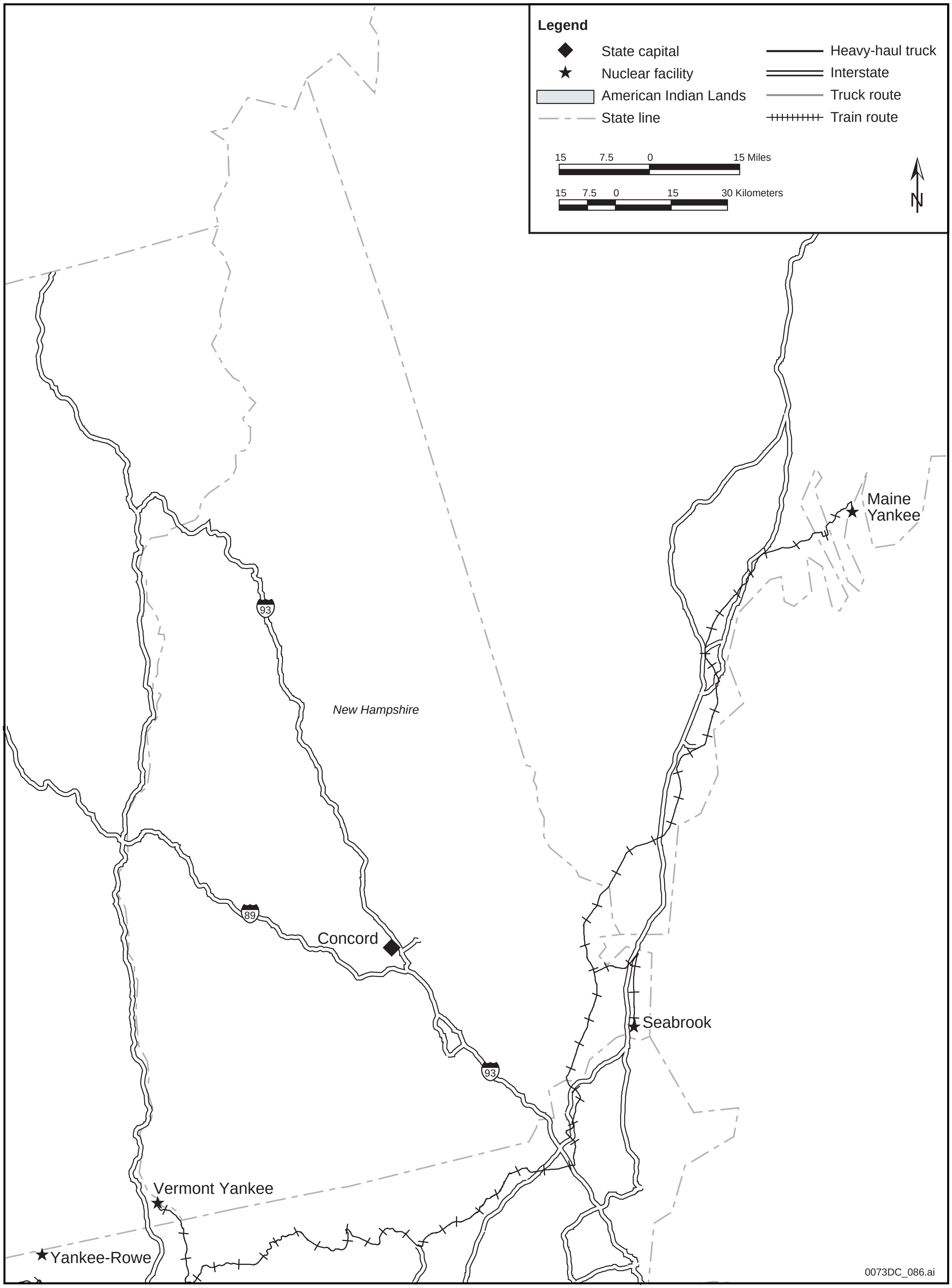

Figure G-28. Representative transportation routes for the State of New Hampshire.

Table G-48. Estimated transportation impacts for the State of New Jersey.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048
Truck	0	0	0	0	0	0	0	0	0	0
Total	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048
Mina										
Rail	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048
Truck	0	0	0	0	0	0	0	0	0	0
Total	276	8.2	56	0.0049	0.033	0.0066	0.031	1.9×10^{-5}	0.0031	0.048

a. Totals might differ from sums of values due to rounding.

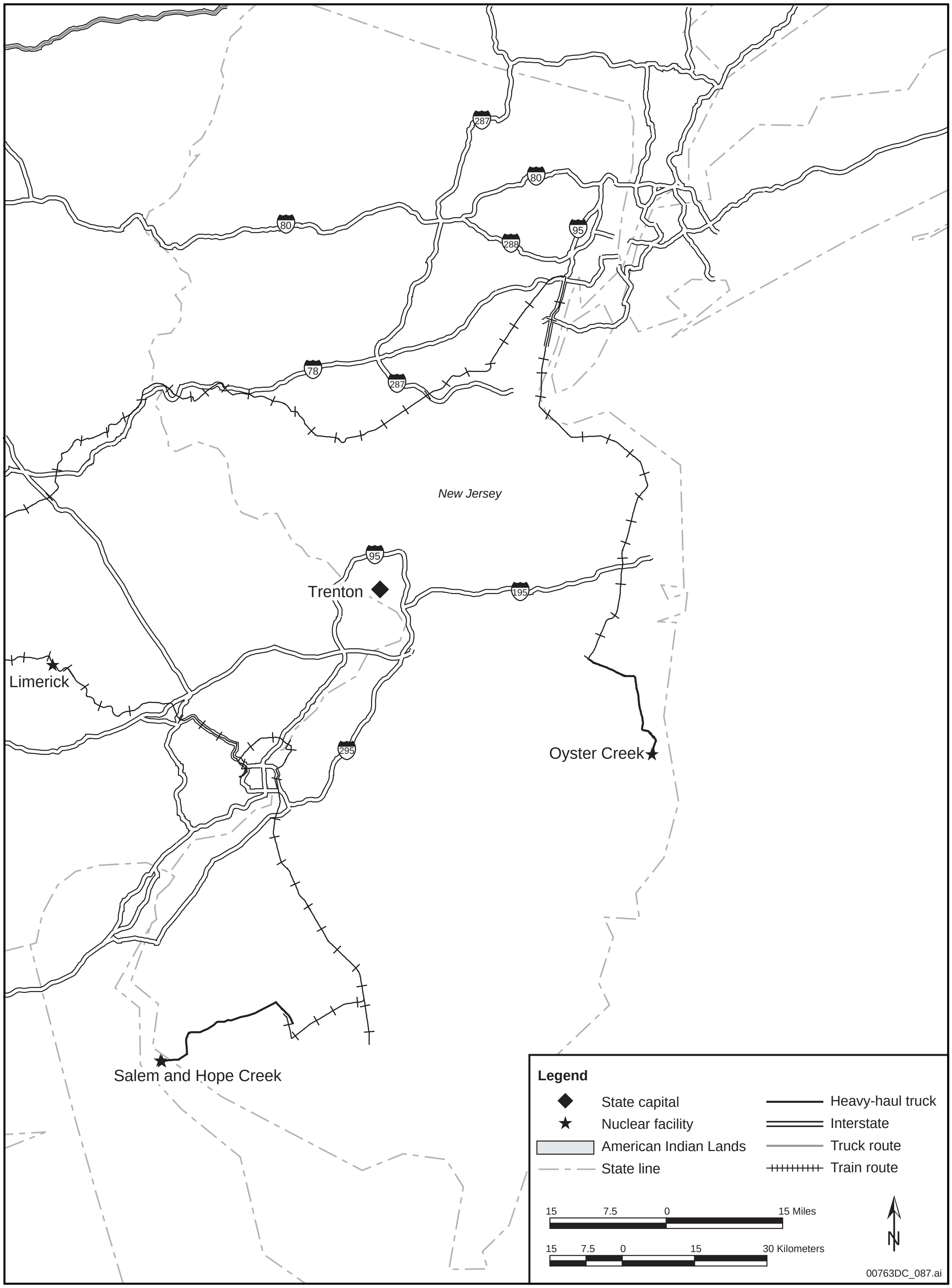

Figure G-29. Representative transportation routes for the State of New Jersey.

Table G-49. Estimated transportation impacts for the State of New Mexico.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	257	0.24	6.0	1.5×10^{-4}	0.0036	3.6×10^{-4}	0.0014	8.6×10^{-7}	0.0043	0.0084
Truck	857	13	34	0.0078	0.020	0.0027	5.7×10^{-4}	3.4×10^{-7}	0.029	0.060
Total	1,114	13	40	0.0080	0.024	0.0031	0.0020	1.2×10^{-6}	0.033	0.069
Mina										
Rail	257	0.17	4.8	9.9×10^{-5}	0.0029	2.5×10^{-4}	9.8×10^{-4}	5.9×10^{-7}	0.0034	0.0067
Truck	857	13	34	0.0078	0.020	0.0027	5.7×10^{-4}	3.4×10^{-7}	0.029	0.060
Total	1,114	13	39	0.0079	0.023	0.0030	0.0015	9.3×10^{-7}	0.033	0.067

a. Totals might differ from sums of values due to rounding.

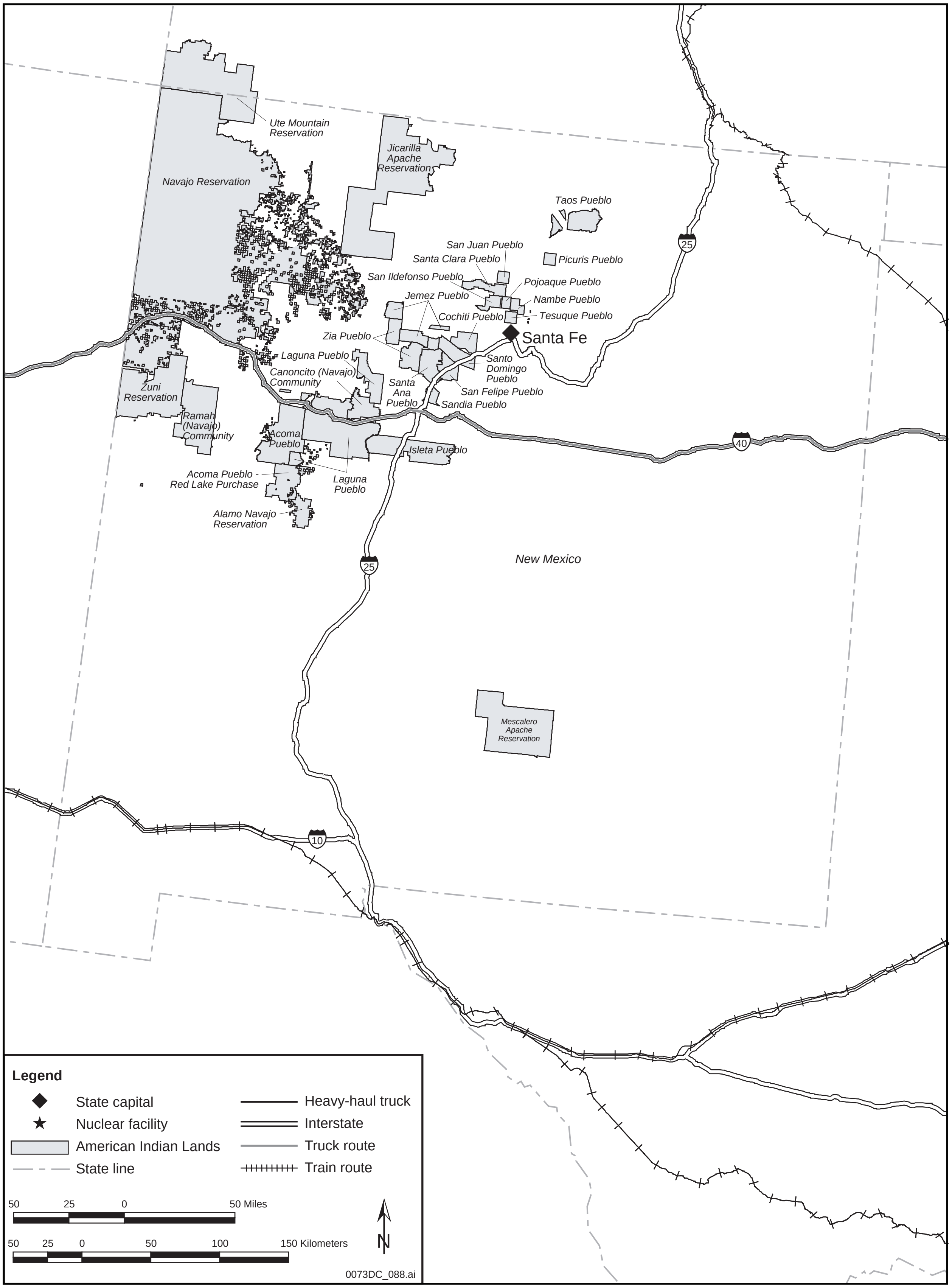

Figure G-30. Representative transportation routes for the State of New Mexico.

Table G-50. Estimated transportation impacts for the State of New York.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	827	14	85	0.0084	0.051	0.018	0.083	5.0×10^{-5}	0.029	0.11
Truck	657	5.4	23	0.0032	0.014	0.0020	0.0013	7.7×10^{-7}	0.0072	0.026
Total	1,484	19	110	0.012	0.065	0.020	0.085	5.1×10^{-5}	0.036	0.13
Mina										
Rail	827	14	85	0.0084	0.051	0.018	0.083	5.0×10^{-5}	0.029	0.11
Truck	657	5.4	23	0.0032	0.014	0.0020	0.0013	7.7×10^{-7}	0.0072	0.026
Total	1,484	19	110	0.012	0.065	0.020	0.085	5.1×10^{-5}	0.036	0.13

a. Totals might differ from sums of values due to rounding.

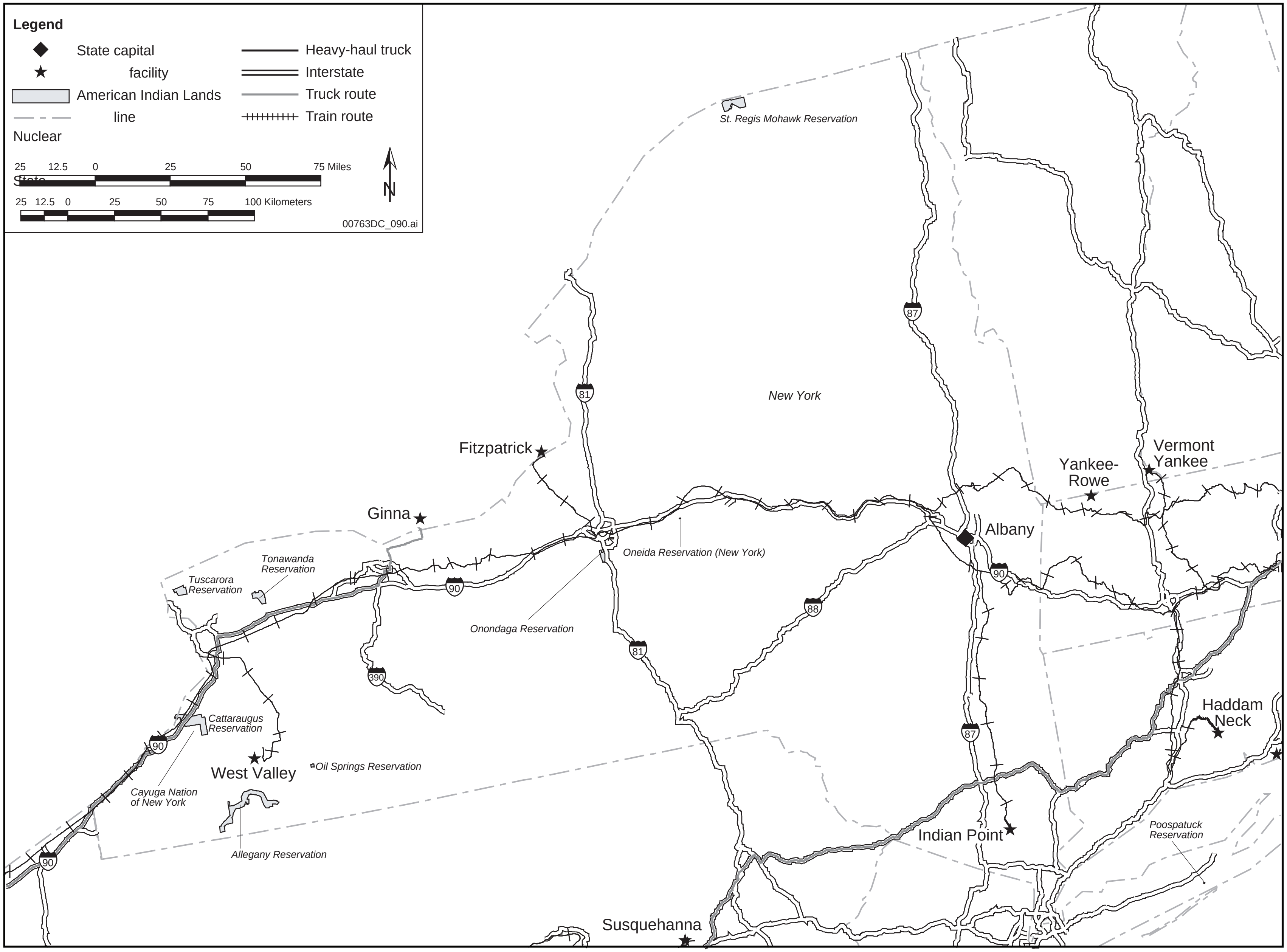

Figure G-31. Representative transportation routes for the State of New York.

Table G-51. Estimated transportation impacts for the State of North Carolina.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046
Truck	0	0	0	0	0	0	0	0	0	0
Total	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046
Mina										
Rail	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046
Truck	0	0	0	0	0	0	0	0	0	0
Total	502	7.1	35	0.0042	0.021	0.011	0.045	2.7×10^{-5}	0.0094	0.046

a. Totals might differ from sums of values due to rounding.

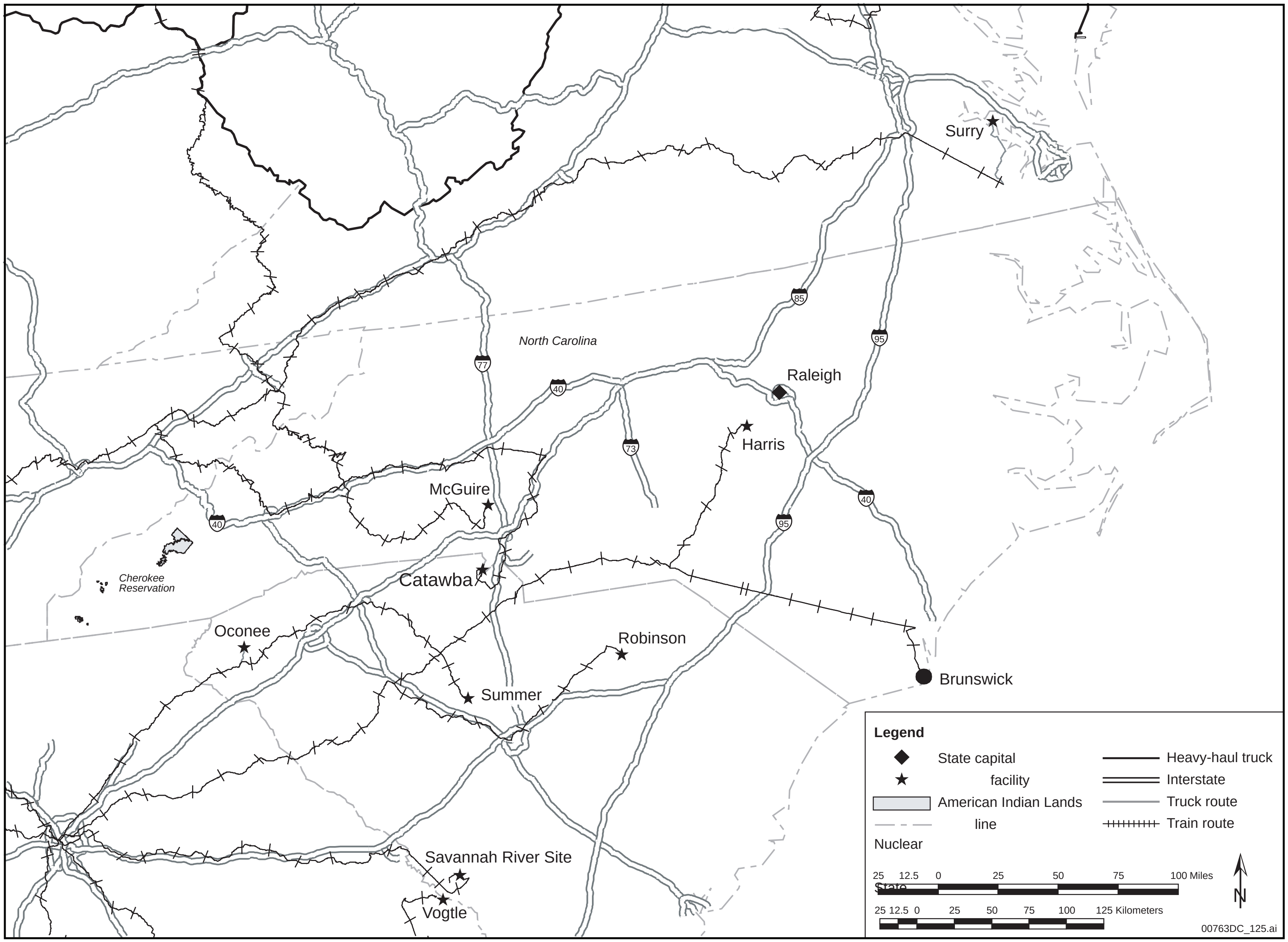

Figure G-32. Representative transportation routes for the State of North Carolina.

Table G-52. Estimated transportation impacts for the State of Ohio.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,314	37	100	0.022	0.062	0.049	0.25	1.5×10^{-4}	0.058	0.19
Truck	657	9.8	18	0.0059	0.011	0.0031	9.6×10^{-4}	5.8×10^{-7}	0.0085	0.028
Total	2,971	47	120	0.028	0.073	0.052	0.25	1.5×10^{-4}	0.066	0.22
Mina										
Rail	2,314	37	100	0.022	0.062	0.049	0.25	1.5×10^{-4}	0.058	0.19
Truck	657	9.8	18	0.0059	0.011	0.0031	9.6×10^{-4}	5.8×10^{-7}	0.0085	0.028
Total	2,971	47	120	0.028	0.073	0.052	0.25	1.5×10^{-4}	0.066	0.22

a. Totals might differ from sums of values due to rounding.

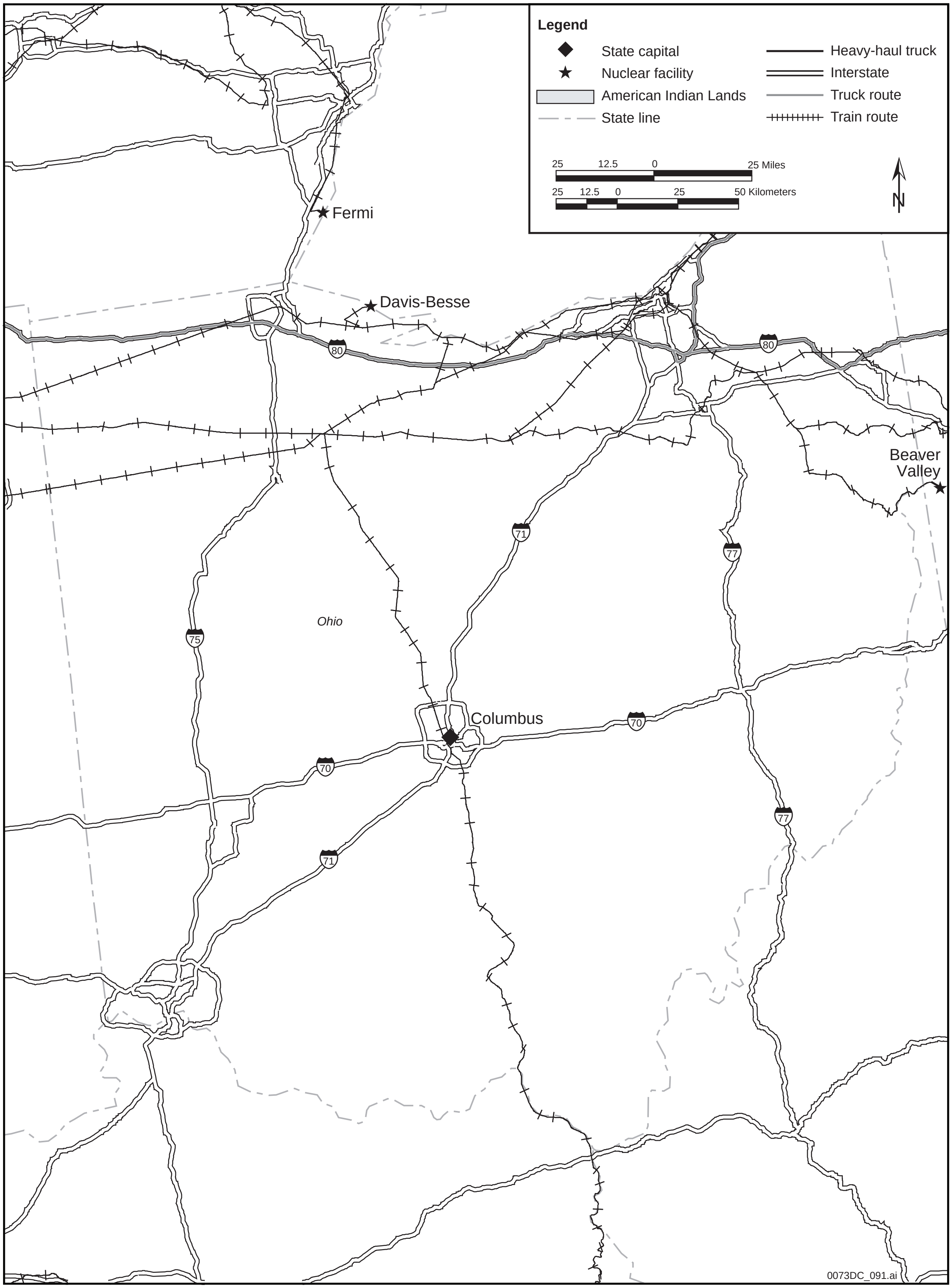

Figure G-33. Representative transportation routes for the State of Ohio.

Table G-53. Estimated transportation impacts for the State of Oklahoma.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	227	0.61	4.9	3.7×10^{-4}	0.0029	0.0010	0.0048	2.9×10^{-6}	0.0033	0.0076
Truck	857	12	26	0.0069	0.015	0.0035	0.0018	1.1×10^{-6}	0.024	0.050
Total	1,084	12	31	0.0073	0.018	0.0045	0.0066	3.9×10^{-6}	0.027	0.057
Mina										
Rail	227	0.61	4.9	3.7×10^{-4}	0.0029	0.0010	0.0048	2.9×10^{-6}	0.0033	0.0076
Truck	857	12	26	0.0069	0.015	0.0035	0.0018	1.1×10^{-6}	0.024	0.050
Total	1,084	12	31	0.0073	0.018	0.0045	0.0066	3.9×10^{-6}	0.027	0.057

a. Totals might differ from sums of values due to rounding.

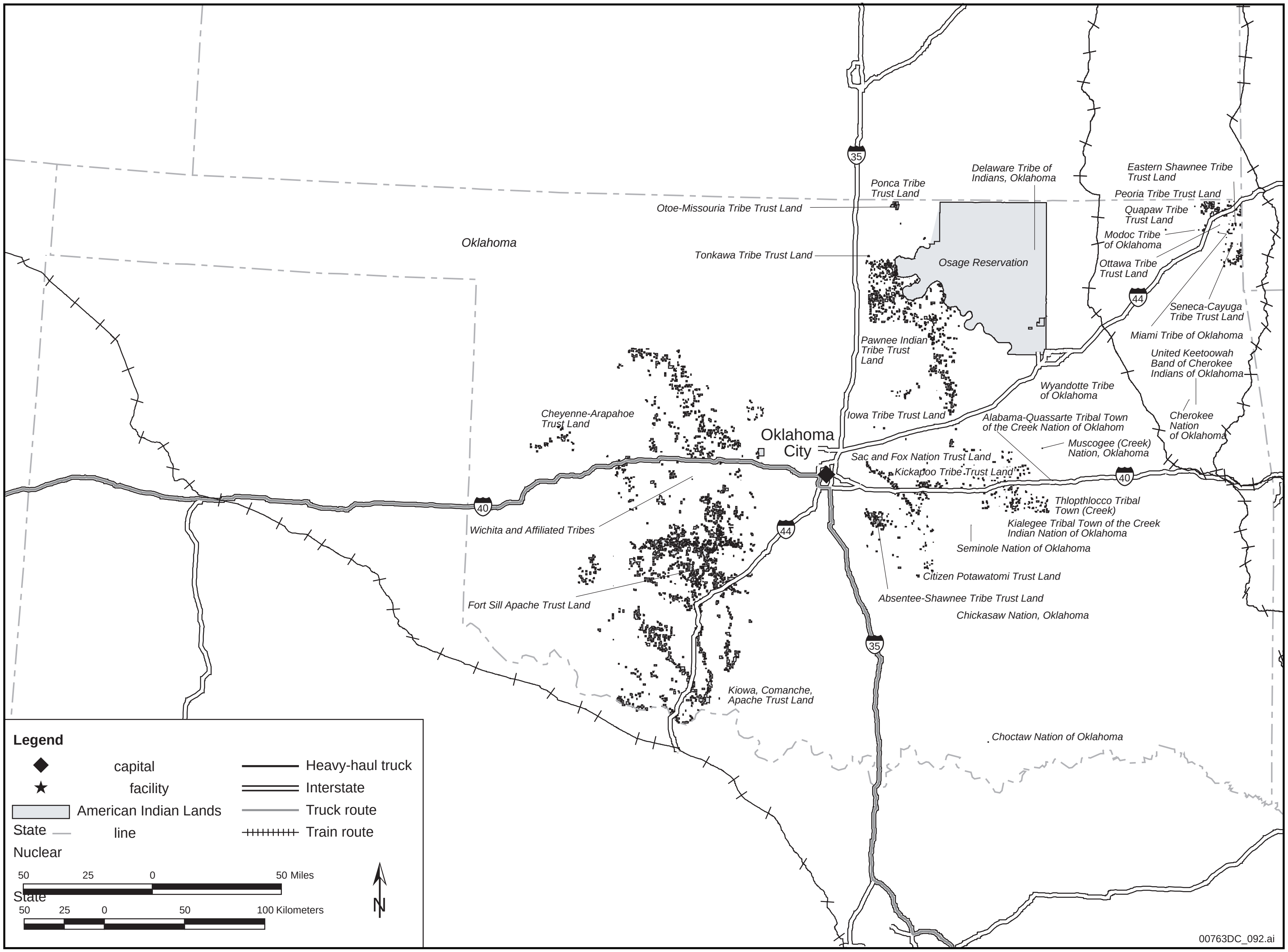

Figure G-34. Representative transportation routes for the State of Oklahoma.

Table G-54. Estimated transportation impacts for the State of Oregon.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,307	7.7	33	0.0046	0.020	0.0091	0.012	7.3×10^{-6}	0.025	0.058
Truck	3	0.024	0.067	1.5×10^{-5}	4.0×10^{-5}	5.7×10^{-6}	2.3×10^{-6}	1.4×10^{-9}	8.5×10^{-5}	1.5×10^{-4}
Total	1,310	7.7	33	0.0046	0.020	0.0091	0.012	7.3×10^{-6}	0.025	0.058
Mina										
Rail	1,307	9.4	53	0.0056	0.032	0.012	0.016	9.3×10^{-6}	0.042	0.091
Truck	3	0.024	0.067	1.5×10^{-5}	4.0×10^{-5}	5.7×10^{-6}	2.3×10^{-6}	1.4×10^{-9}	8.5×10^{-5}	1.5×10^{-4}
Total	1,310	9.4	53	0.0056	0.032	0.012	0.016	9.3×10^{-6}	0.042	0.091

a. Totals might differ from sums of values due to rounding.

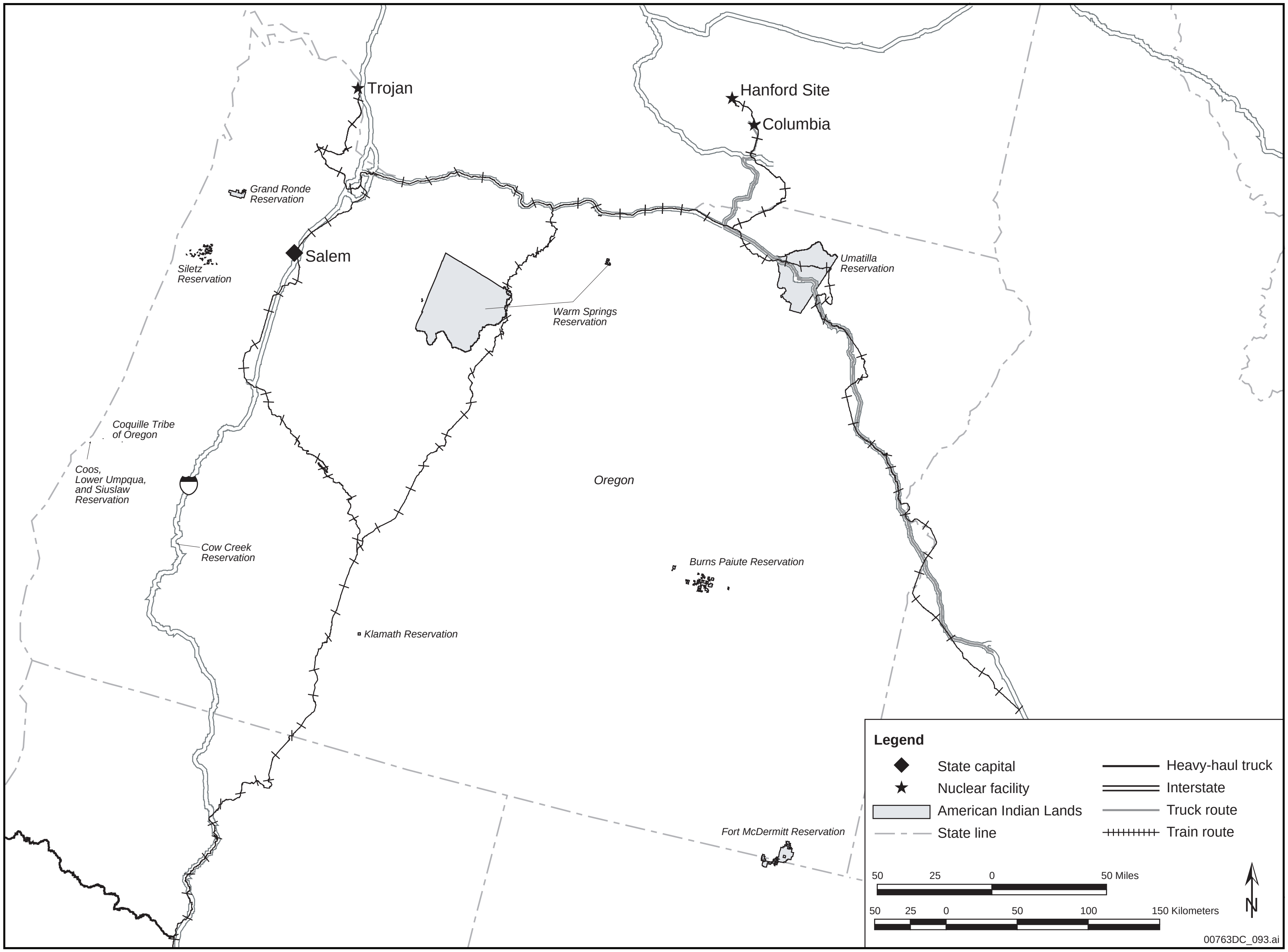

Figure G-35. Representative transportation routes for the State of Oregon.

Table G-55. Estimated transportation impacts for the Commonwealth of Pennsylvania.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,036	39	130	0.023	0.080	0.047	0.24	1.4×10^{-4}	0.042	0.19
Truck	657	6.1	15	0.0037	0.0087	0.0012	0.0012	7.1×10^{-7}	0.013	0.027
Total	2,693	45	150	0.027	0.089	0.048	0.24	1.4×10^{-4}	0.056	0.22
Mina										
Rail	2,036	39	130	0.023	0.080	0.047	0.24	1.4×10^{-4}	0.042	0.19
Truck	657	6.1	15	0.0037	0.0087	0.0012	0.0012	7.1×10^{-7}	0.013	0.027
Total	2,693	45	150	0.027	0.089	0.048	0.24	1.4×10^{-4}	0.056	0.22

a. Totals might differ from sums of values due to rounding.

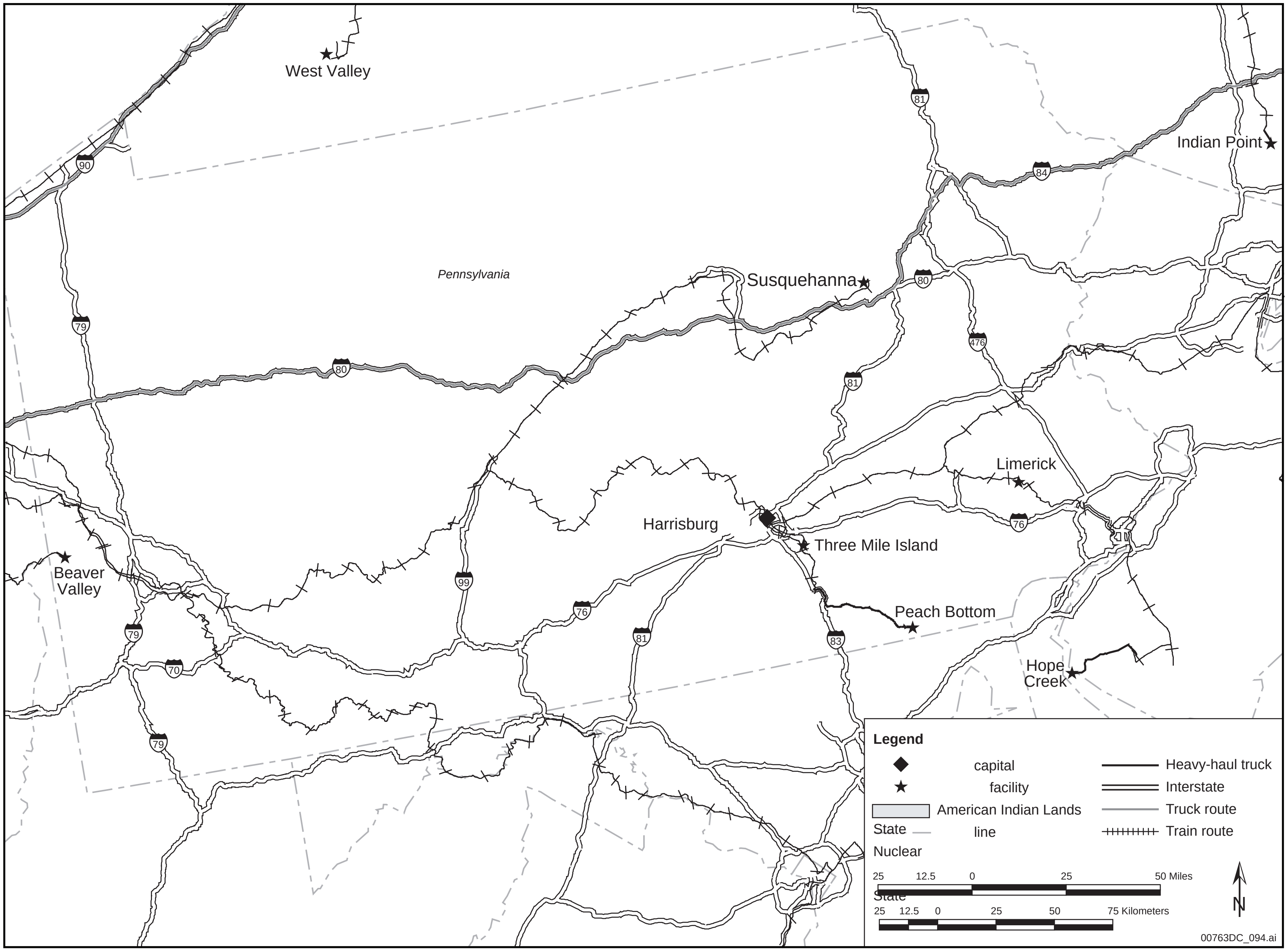

Figure G-36. Representative transportation routes for the Commonwealth of Pennsylvania.

Table G-56. Estimated transportation impacts for the State of South Carolina.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070
Mina										
Rail	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070
Truck	0	0	0	0	0	0	0	0	0	0
Total	1,365	4.6	93	0.0027	0.056	0.0035	0.015	8.8×10^{-6}	0.0083	0.070

a. Totals might differ from sums of values due to rounding.

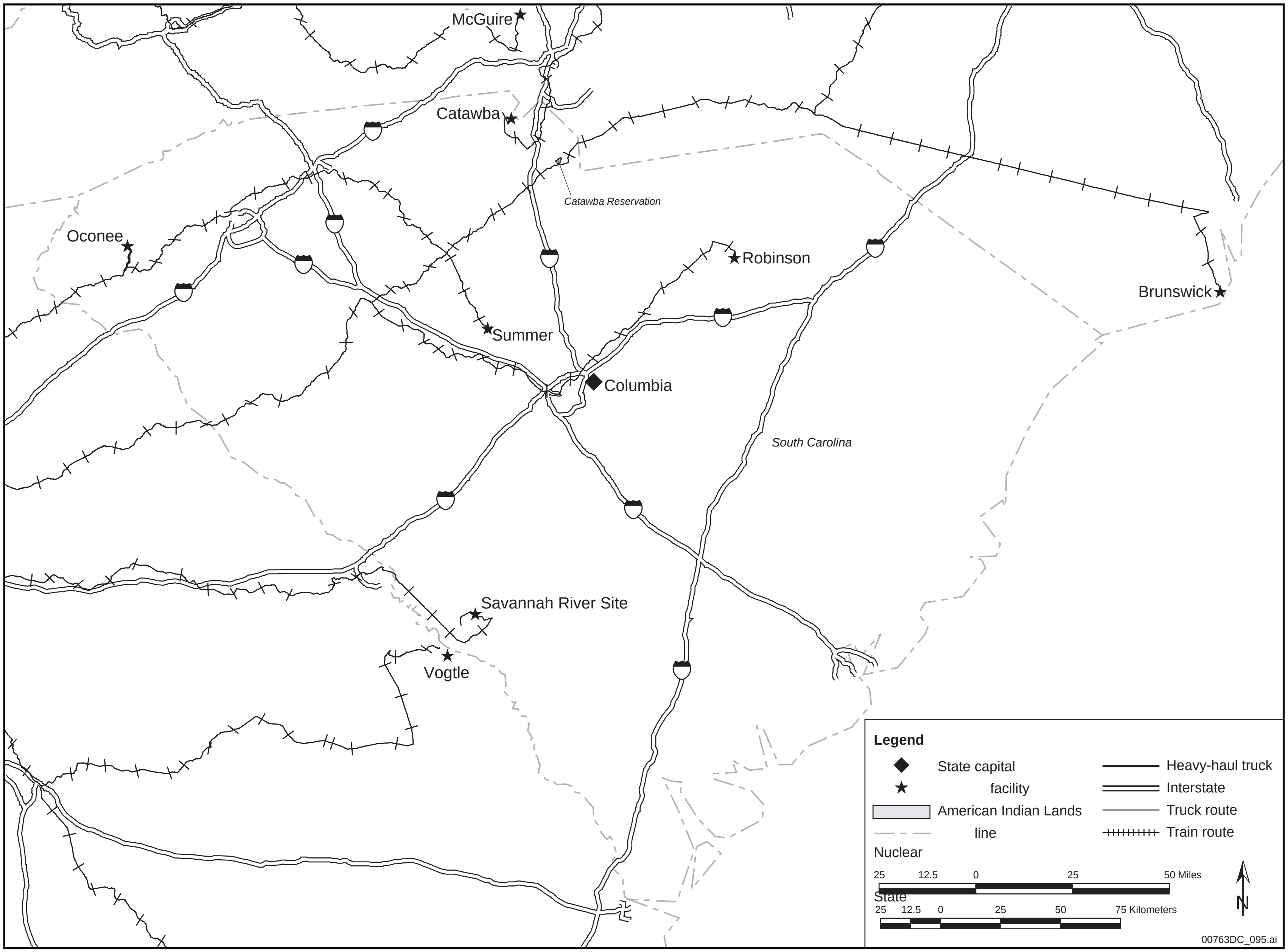

Figure G-37. Representative transportation routes for the State of South Carolina.

Table G-57. Estimated transportation impacts for the State of South Dakota.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}
Truck	0	0	0	0	0	0	0	0	0	0
Total	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}
Mina										
Rail	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}
Truck	0	0	0	0	0	0	0	0	0	0
Total	44	0.0045	0.081	2.7×10^{-6}	4.9×10^{-5}	8.1×10^{-6}	5.6×10^{-5}	3.4×10^{-8}	5.6×10^{-5}	1.2×10^{-4}

a. Totals might differ from sums of values due to rounding.

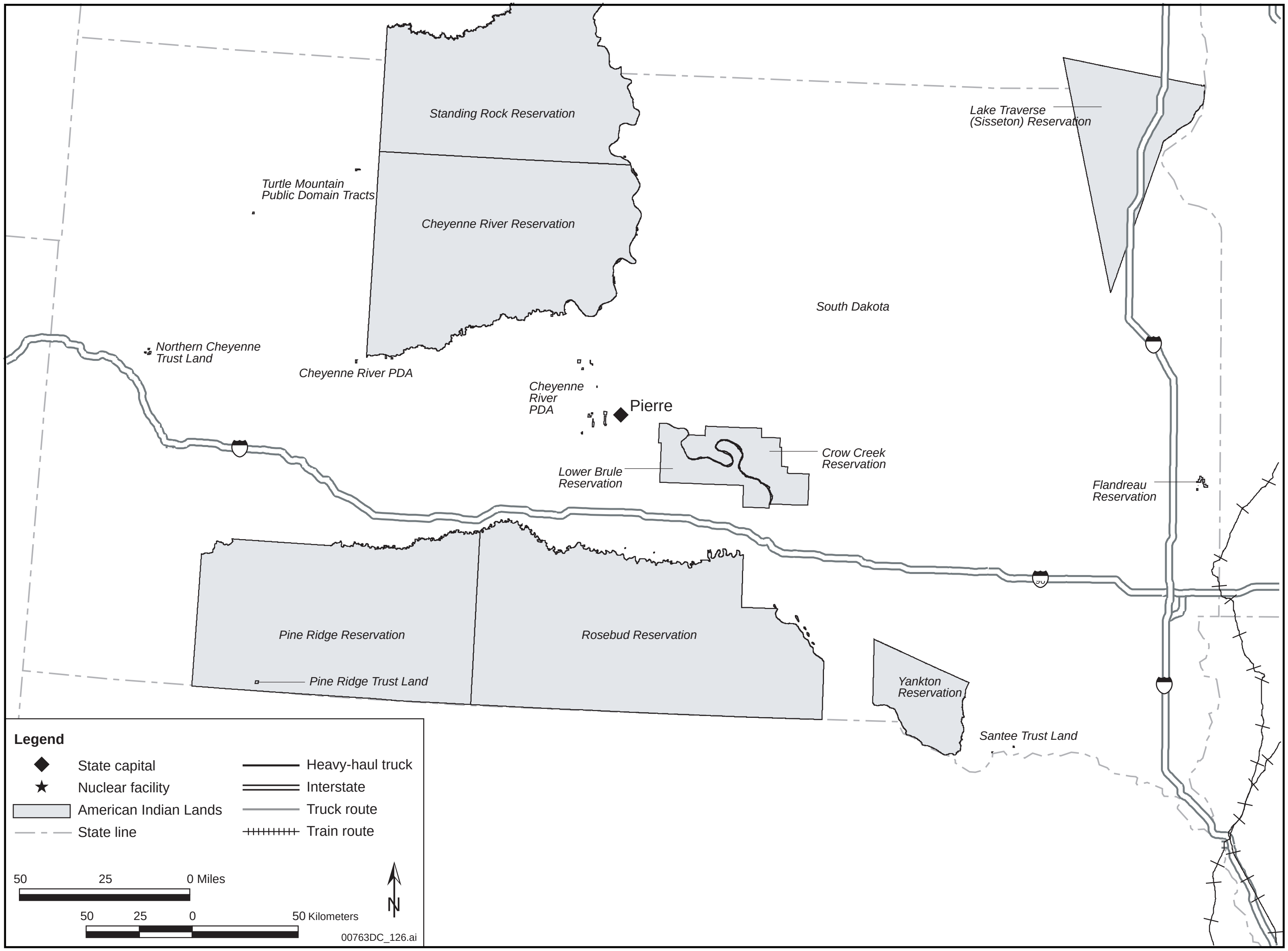

Figure G-38. Representative transportation routes for the State of South Dakota.

Table G-58. Estimated transportation impacts for the State of Tennessee.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14
Mina										
Rail	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14
Truck	0	0	0	0	0	0	0	0	0	0
Total	2,663	29	70	0.018	0.042	0.039	0.12	7.1×10^{-5}	0.040	0.14

a. Totals might differ from sums of values due to rounding.

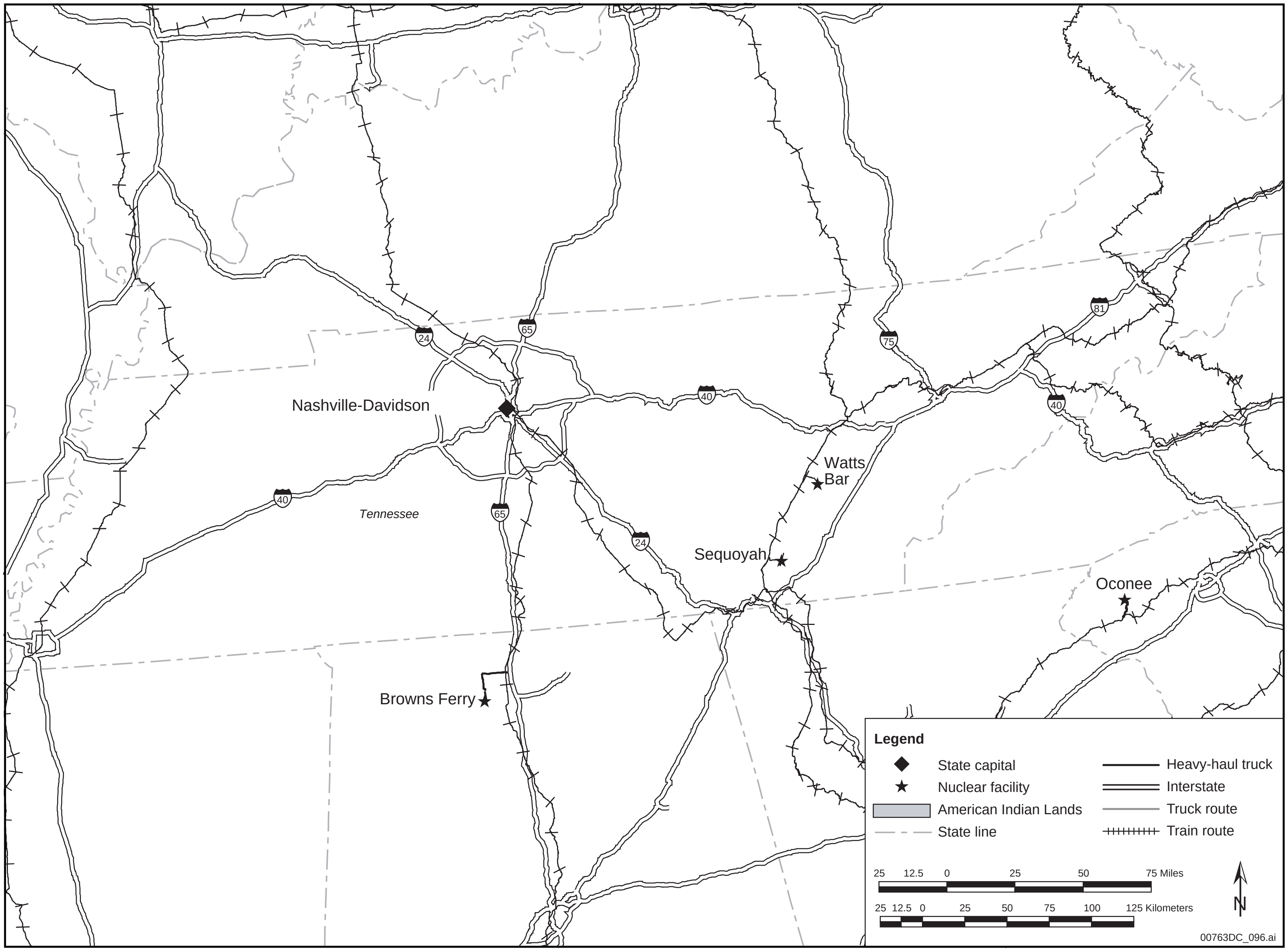

Figure G-39. Representative transportation routes for the State of Tennessee.

Table G-59. Estimated transportation impacts for the State of Texas.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	357	15	41	0.0087	0.025	0.020	0.076	4.6×10^{-5}	0.021	0.074
Truck	857	30	39	0.018	0.023	0.019	0.021	1.2×10^{-5}	0.035	0.096
Total	1,214	44	80	0.027	0.048	0.039	0.097	5.8×10^{-5}	0.056	0.17
Mina										
Rail	357	12	39	0.0073	0.023	0.017	0.064	3.8×10^{-5}	0.019	0.066
Truck	857	30	39	0.018	0.023	0.019	0.021	1.2×10^{-5}	0.035	0.096
Total	1,214	42	78	0.025	0.047	0.035	0.085	5.1×10^{-5}	0.055	0.16

a. Totals might differ from sums of values due to rounding.

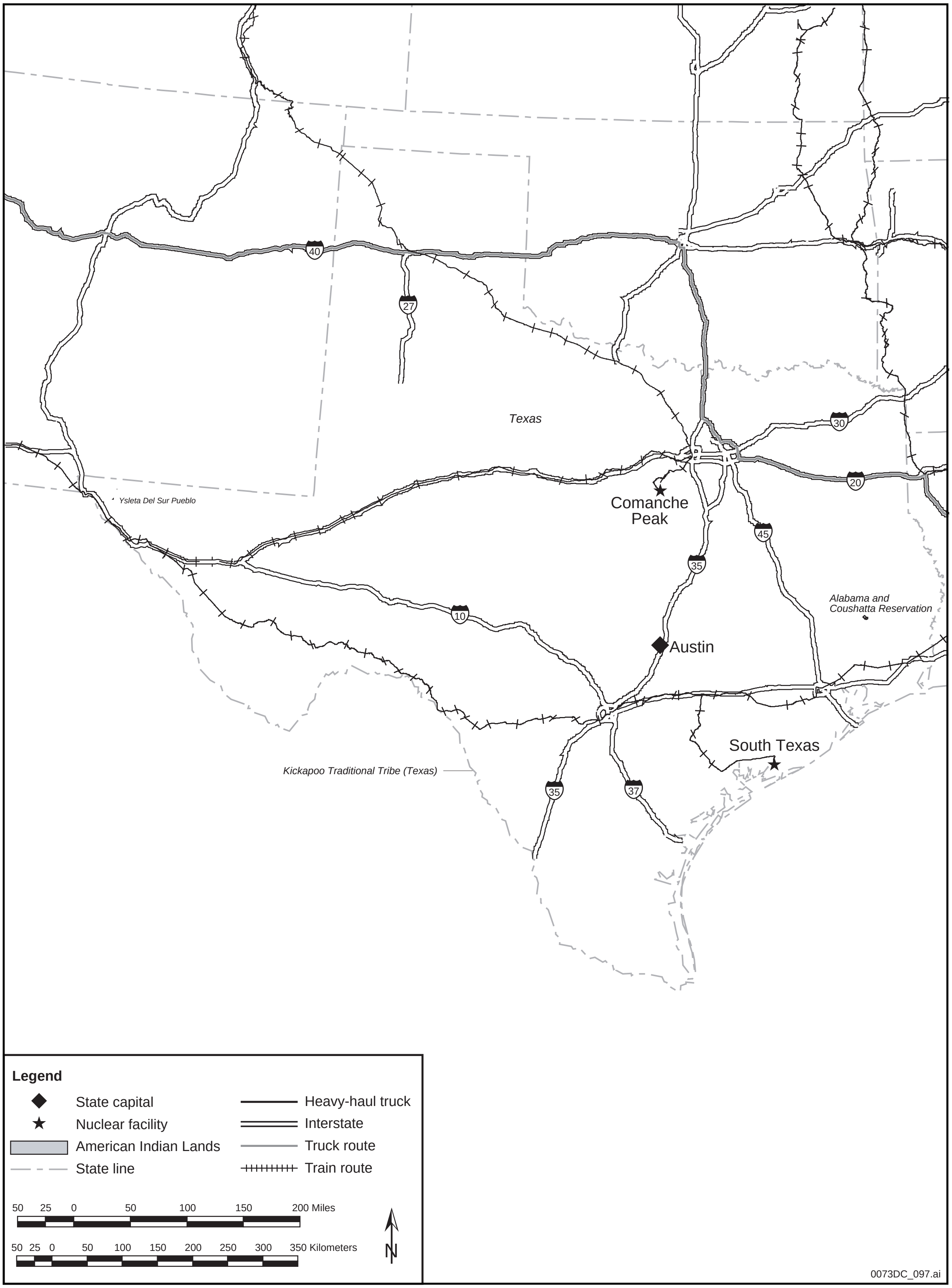

Figure G-40. Representative transportation routes for the State of Texas.

Table G-60. Estimated transportation impacts for the State of Utah.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	8,740	190	950	0.12	0.57	0.23	0.80	4.8×10^{-4}	0.31	1.2
Truck	1,793	50	73	0.030	0.044	0.030	0.016	9.5×10^{-6}	0.063	0.17
Total	10,533	240	1,000	0.15	0.62	0.26	0.81	4.9×10^{-4}	0.38	1.4
Mina										
Rail	7,532	33	420	0.020	0.25	0.045	0.19	1.1×10^{-4}	0.14	0.45
Truck	1,793	50	73	0.030	0.044	0.030	0.016	9.5×10^{-6}	0.063	0.17
Total	9,325	83	490	0.050	0.30	0.075	0.21	1.2×10^{-4}	0.20	0.62

a. Totals might differ from sums of values due to rounding.

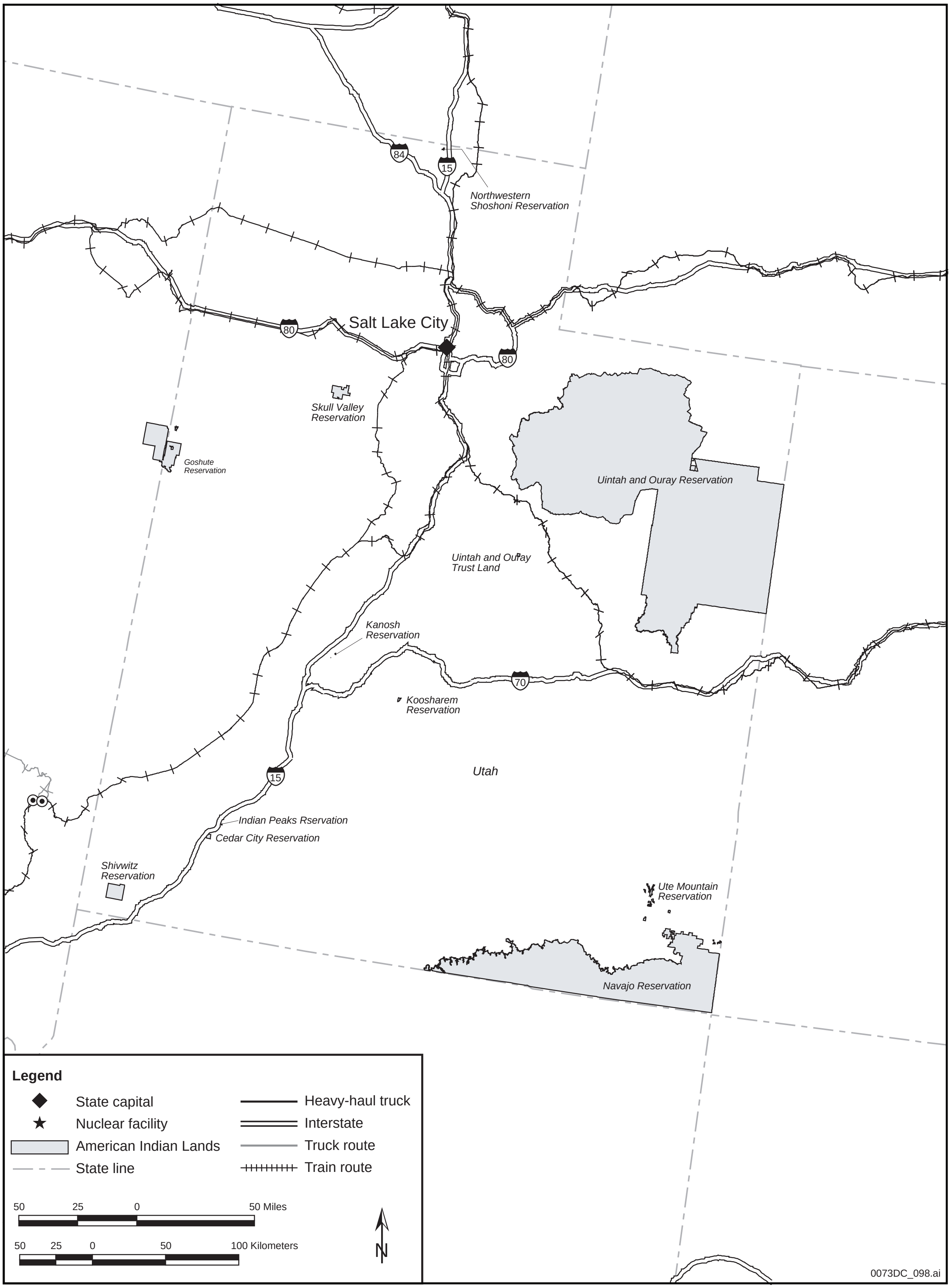

Figure G-41. Representative transportation routes for the State of Utah.

Table G-61. Estimated transportation impacts for the State of Vermont.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028
Truck	0	0	0	0	0	0	0	0	0	0
Total	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028
Mina										
Rail	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028
Truck	0	0	0	0	0	0	0	0	0	0
Total	199	0.087	4.2	5.2×10^{-5}	0.0025	3.9×10^{-5}	2.1×10^{-4}	1.3×10^{-7}	1.9×10^{-4}	0.0028

a. Totals might differ from sums of values due to rounding.

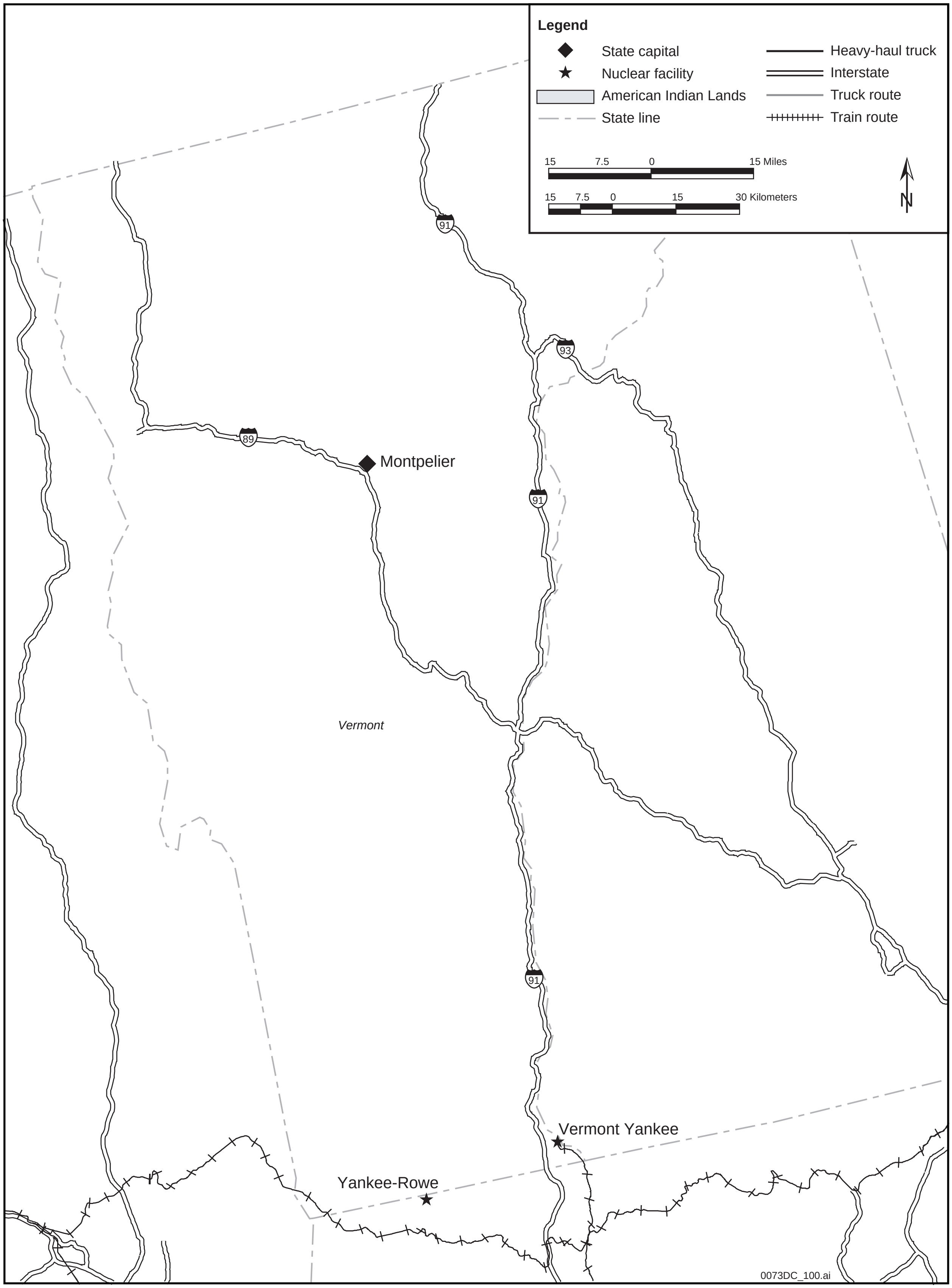

Figure G-42. Representative transportation routes for the State of Vermont.

Table G-62. Estimated transportation impacts for the Commonwealth of Virginia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041
Truck	0	0	0	0	0	0	0	0	0	0
Total	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041
Mina										
Rail	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041
Truck	0	0	0	0	0	0	0	0	0	0
Total	390	5.9	40	0.0036	0.024	0.0060	0.023	1.4×10^{-5}	0.0078	0.041

a. Totals might differ from sums of values due to rounding.

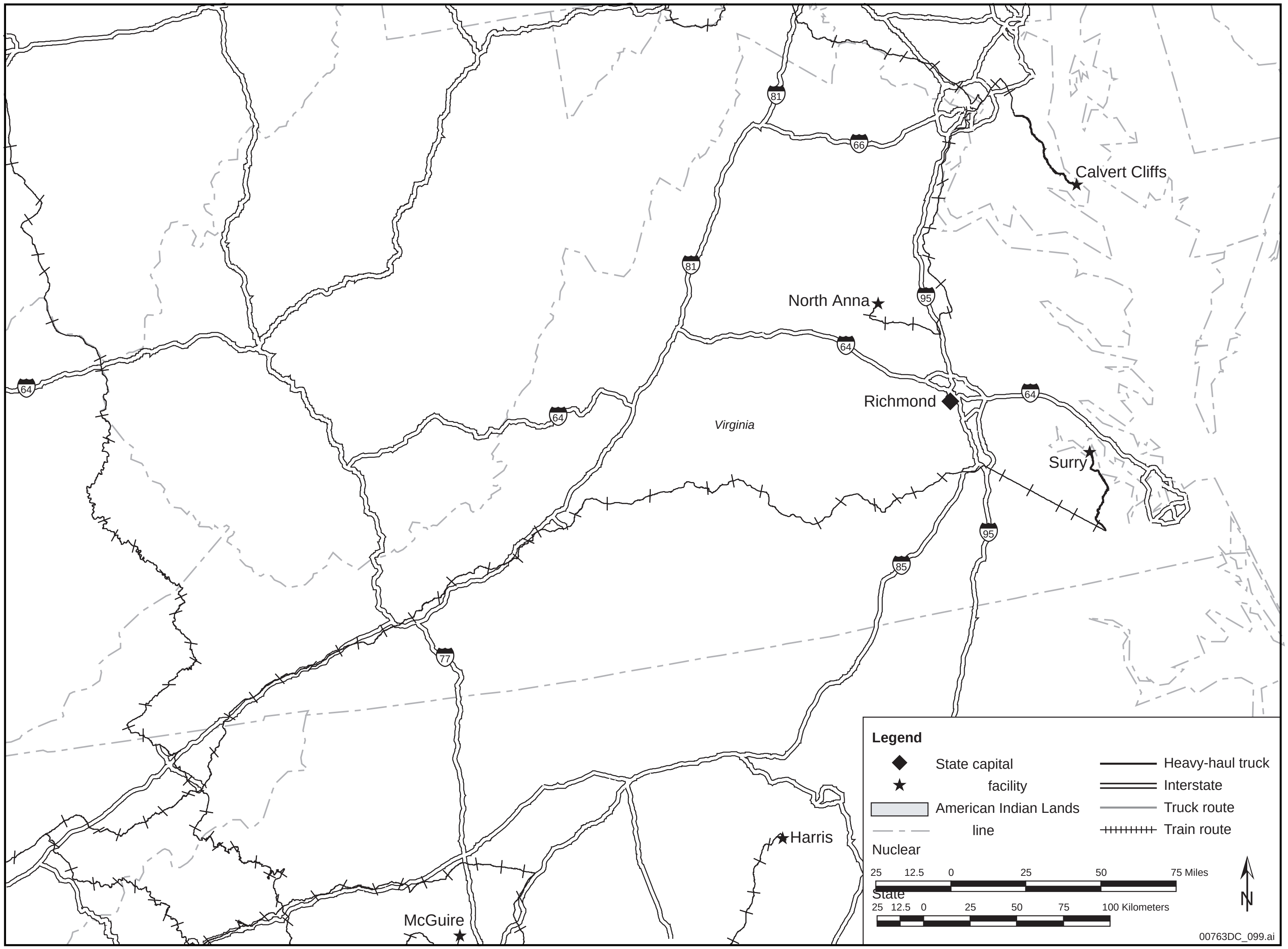

Figure G-43. Representative transportation routes for the Commonwealth of Virginia.

Table G-63. Estimated transportation impacts for the State of Washington.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	1,274	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062
Truck	3	0.0098	0.15	5.9×10^{-6}	9.3×10^{-5}	4.9×10^{-6}	2.4×10^{-6}	1.4×10^{-9}	6.8×10^{-6}	1.1×10^{-4}
Total	1,277	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062
Mina										
Rail	1,274	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062
Truck	3	0.0098	0.15	5.9×10^{-6}	9.3×10^{-5}	4.9×10^{-6}	2.4×10^{-6}	1.4×10^{-9}	6.8×10^{-6}	1.1×10^{-4}
Total	1,277	7.9	73	0.0047	0.044	0.0066	0.0045	2.7×10^{-6}	0.0066	0.062

a. Totals might differ from sums of values due to rounding.

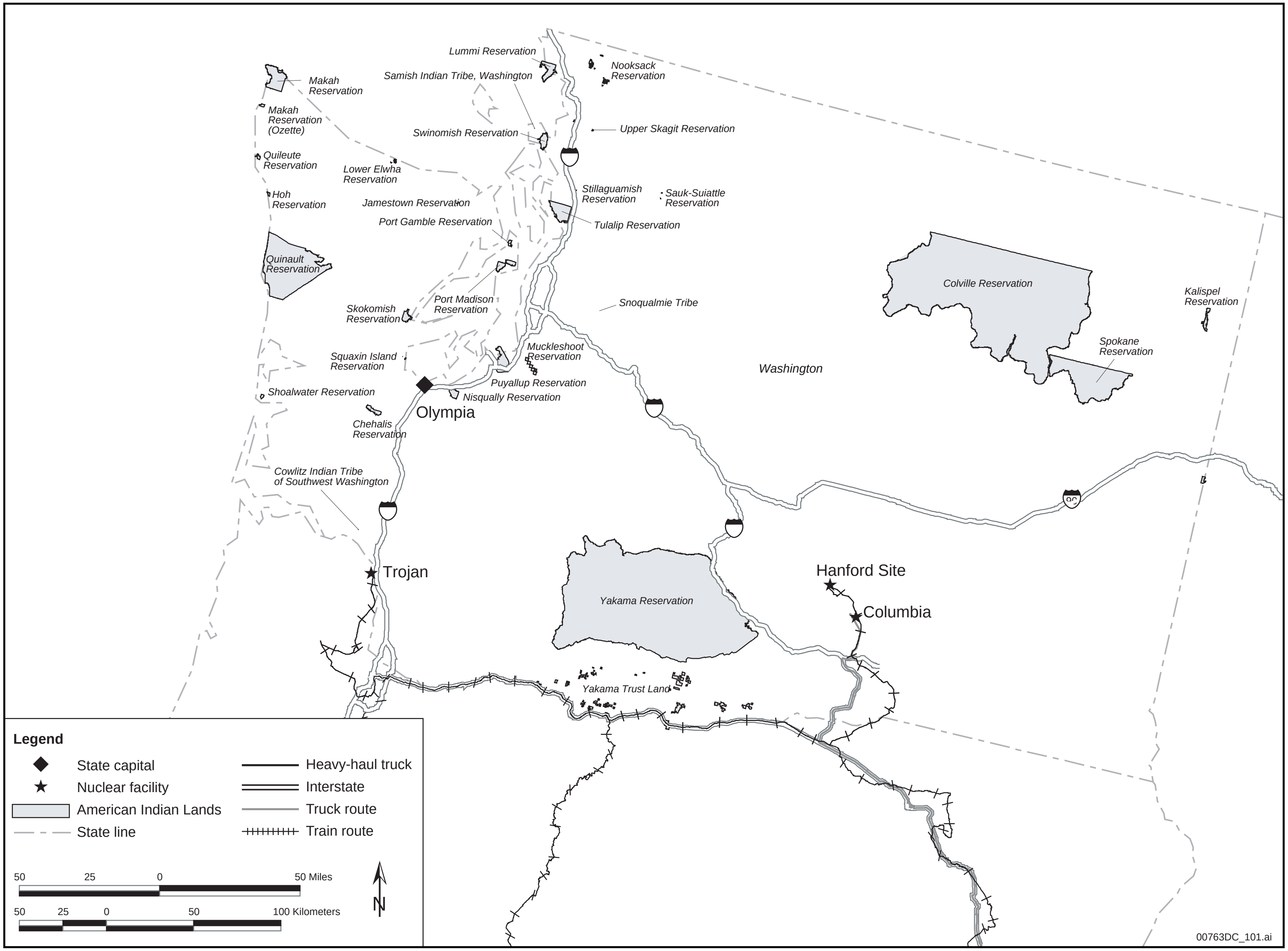

Figure G-44. Representative transportation routes for the State of Washington.

Table G-64. Estimated transportation impacts for the State of West Virginia.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048
Mina										
Rail	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048
Truck	0	0	0	0	0	0	0	0	0	0
Total	255	0.30	3.3	1.8×10^{-4}	0.0020	4.6×10^{-4}	0.0018	1.1×10^{-6}	0.0022	0.0048

a. Totals might differ from sums of values due to rounding.

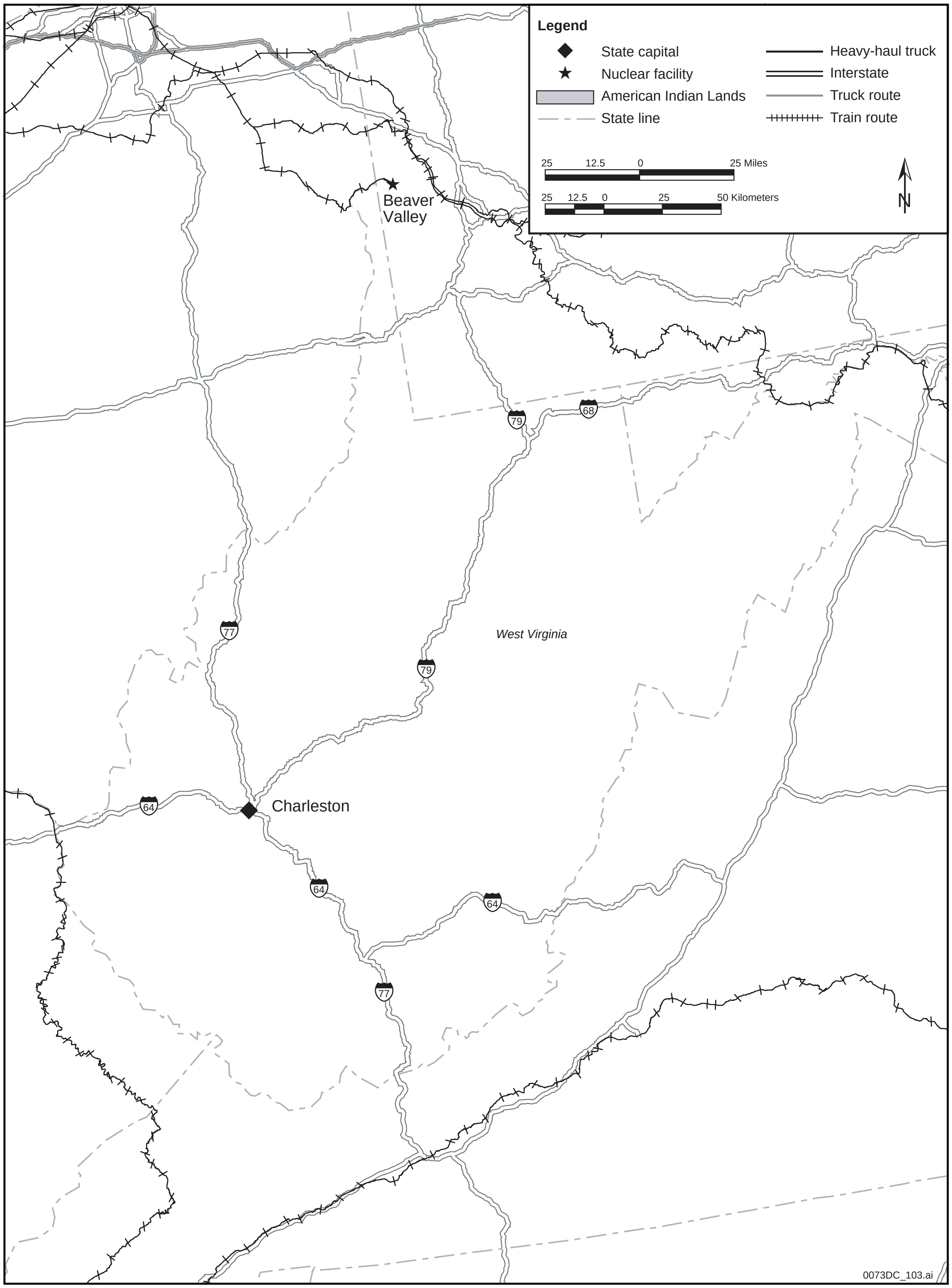

Figure G-45. Representative transportation routes for the State of West Virginia.

Table G-65. Estimated transportation impacts for the State of Wisconsin.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	152	3.5	33	0.0021	0.020	0.0031	0.013	7.6×10^{-6}	0.0038	0.029
Truck	37	0.089	1.8	5.3×10^{-5}	0.0011	4.4×10^{-5}	3.7×10^{-5}	2.2×10^{-8}	7.5×10^{-5}	0.0012
Total	189	3.5	34	0.0021	0.021	0.0031	0.013	7.6×10^{-6}	0.0038	0.030
Mina										
Rail	152	3.5	33	0.0021	0.020	0.0031	0.013	7.6×10^{-6}	0.0038	0.029
Truck	37	0.089	1.8	5.3×10^{-5}	0.0011	4.4×10^{-5}	3.7×10^{-5}	2.2×10^{-8}	7.5×10^{-5}	0.0012
Total	189	3.5	34	0.0021	0.021	0.0031	0.013	7.6×10^{-6}	0.0038	0.030

a. Totals might differ from sums of values due to rounding.

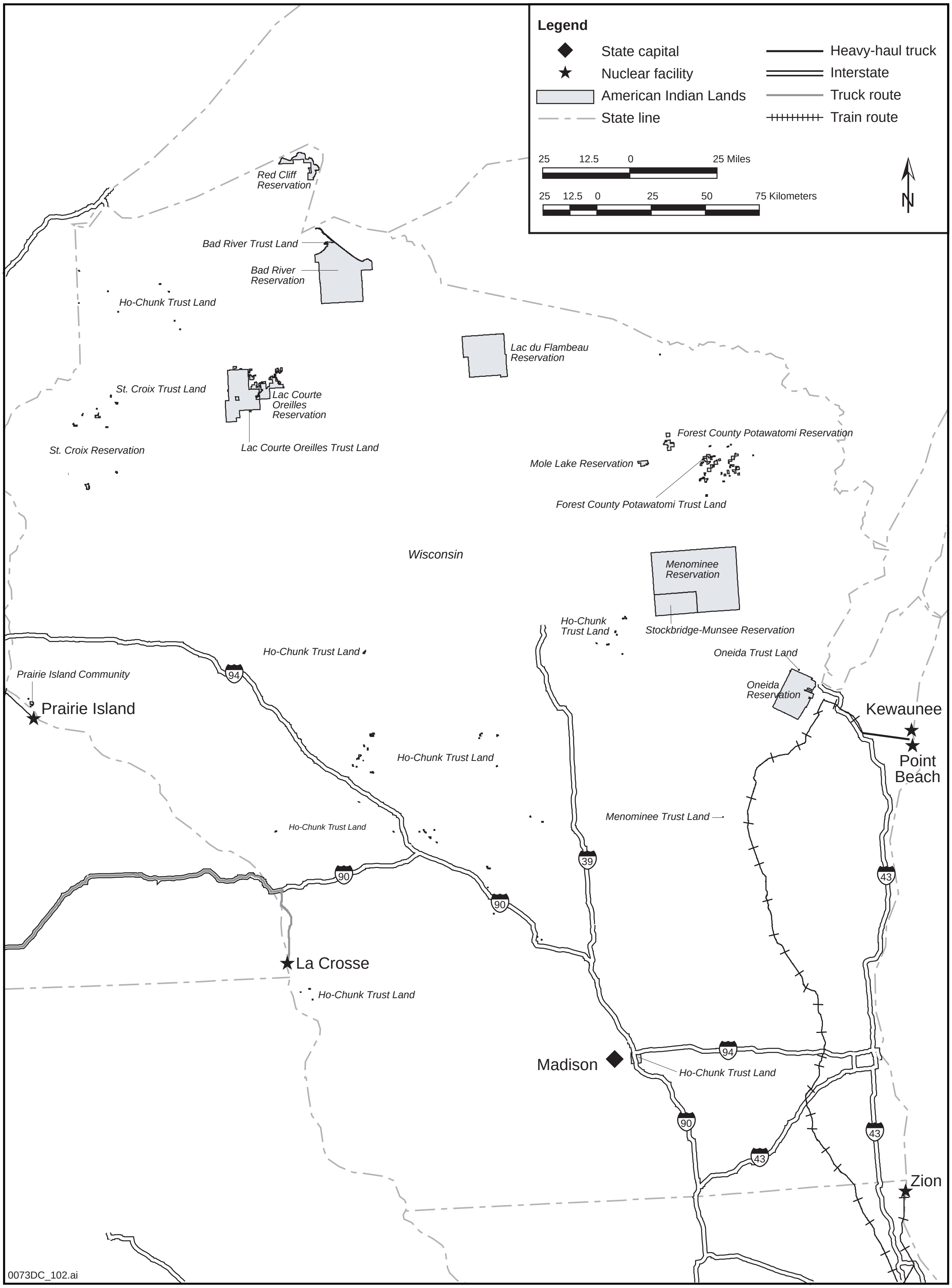

Figure G-46. Representative transportation routes for the State of Wisconsin.

Table G-66. Estimated transportation impacts for the State of Wyoming.

Rail alignment	No. of casks	Members of the public radiation dose (person-rem)	Involved workers radiation dose (person-rem)	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident dose risk (person-rem)	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente										
Rail	6,354	18	390	0.011	0.23	0.025	0.11	6.4×10^{-5}	0.28	0.55
Truck	1,789	23	77	0.014	0.046	0.0022	0.0027	1.6×10^{-6}	0.062	0.12
Total	8,143	41	470	0.025	0.28	0.027	0.11	6.5×10^{-5}	0.34	0.67
Mina										
Rail	6,354	18	390	0.011	0.23	0.025	0.11	6.4×10^{-5}	0.28	0.55
Truck	1,789	23	77	0.014	0.046	0.0022	0.0027	1.6×10^{-6}	0.062	0.12
Total	8,143	41	470	0.025	0.28	0.027	0.11	6.5×10^{-5}	0.34	0.67

a. Totals might differ from sums of values due to rounding.

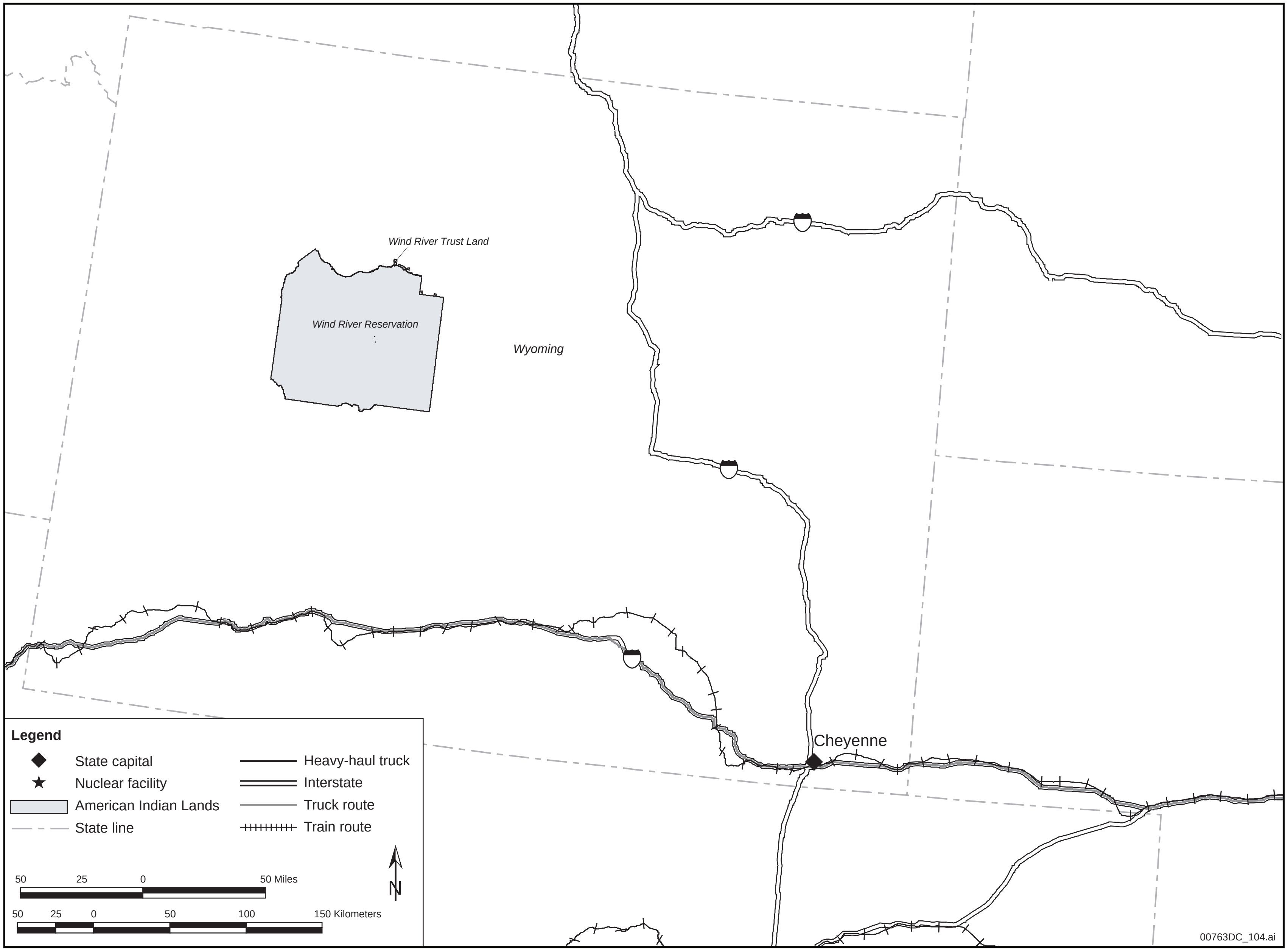

Figure G-47. Representative transportation routes for the State of Wyoming.

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Appendix H

Supplemental Transportation Information

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H. SUPPLEMENTAL TRANSPORTATION INFORMATION

H.1 Introduction

The U.S. Department of Energy (DOE or the Department) developed this appendix to provide general background information on transportation-related topics. Although this information is not essential for analysis of potential impacts from the transportation of spent nuclear fuel and high-level radioactive waste to a repository at Yucca Mountain, Nevada, it will help readers to understand how the transportation system would operate within the regulatory framework for the transportation of these materials. Section H.2 discusses transportation regulations, Section H.3 describes the components of a transportation system, and Section H.4 discusses operational practices. Section H.5 describes cask safety and testing. Section H.6 discusses emergency response, and Section H.7 describes available assistance for state, local, and American Indian tribal governments for emergency response planning. Section H.8 discusses DOE plans for transportation security, and Section H.9 describes potential liability under the *Price-Anderson Act* [Section 170 of the *Atomic Energy Act*, as amended (42 U.S.C. 2011 et seq.)].

Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation, the component elements of which have not been separated by reprocessing. In this document, the term refers to the special nuclear material, byproduct material, source material, and other radioactive materials associated with fuel assemblies and includes commercial spent nuclear fuel (including mixed-oxide fuel) from civilian nuclear power reactors, and DOE spent nuclear fuel from DOE and non-DOE production reactors, naval reactors, test and experimental reactors, and research reactors. Naval spent nuclear fuel shipments to the repository would be conducted under the authority of Presidential Executive Order 12344 and Public Law 106-65 and would be in compliance with applicable sections of the Code of Federal Regulations.

Most nuclear power reactors use solid uranium dioxide ceramic pellets of low-enriched uranium for fuel. The pellets are sealed in strong metal tubes, which are bundled together to form a nuclear fuel assembly. Depending on the type of reactor, typical fuel assemblies can be as long as 4.9 meters (16 feet) and weigh up to 540 kilograms (1,200 pounds). After a period in a reactor, the fuel is no longer efficient for the production of power and the assembly is removed from the reactor. After removal, the assembly (now called spent nuclear fuel) is highly radioactive and requires heavy shielding and remote handling to protect workers and the public.

High-level radioactive waste is the highly radioactive material that resulted from the reprocessing of spent nuclear fuel; it includes liquid waste that was produced directly in reprocessing and any solid material from such liquid waste that contains fission products in sufficient concentrations. High-level radioactive waste also includes other highly radioactive material that the U.S. Nuclear Regulatory Commission (NRC), consistent with existing law, has determined by rule to require permanent isolation. Immobilized surplus weapons-usable plutonium is part of the high-level radioactive waste inventory. All high-level radioactive waste would be in a solid form before DOE would ship it to Yucca Mountain.

H.2 Transportation Regulations

The shipment of spent nuclear fuel and high-level radioactive waste is highly regulated. For transportation of these materials to Yucca Mountain, DOE would meet or exceed U.S. Department of

Transportation and NRC rules. DOE would also work with states, local government officials, federally recognized American Indian tribes, utilities, the transportation industry, and other interested parties in a cooperative manner to develop the transportation system.

The *Hazardous Materials Transportation Act*, as amended (49 U.S.C. 1801 et seq.), directs the U.S. Department of Transportation to develop transportation safety standards for hazardous materials, including radioactive materials. Title 49 of the Code of Federal Regulations contains U.S. Department of Transportation standards and requirements for the packaging, transporting, and handling of radioactive materials for all modes of transportation. NRC sets additional design and performance standards for packages that carry materials with higher levels of radioactivity.

The *Nuclear Waste Policy Act*, as amended (42 U.S.C. 10101 et seq.; NWPA), requires that all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain be in NRC-certified casks and in accordance with NRC regulations related to advance notification of state and local governments. In addition, DOE has committed to notification of American Indian tribal governments for these shipments (DIRS 171934-DOE 2002, p. 23). NRC rules do not require notification of local authorities, which is the responsibility of the individual state governments. This section discusses the key regulations that govern the transportation of spent nuclear fuel and high-level radioactive waste.

H.2.1 PACKAGING

The primary means for the protection of people and the environment during radioactive materials shipment is the use of radioactive materials packages that meet U.S. Department of Transportation and NRC requirements. Packages are selected based on activity, type, and form of the material to be shipped. All spent nuclear fuel and high-level radioactive waste shipments to Yucca Mountain would be in Type B casks, which have the most stringent design standards to prevent release of radioactive materials under normal conditions of transport and during hypothetical accidents (Section H.4.10 discusses accident conditions). NRC regulates and certifies the design, manufacture, testing, and use of Type B packages under regulations in 10 CFR Part 71. All shippers must properly package radioactive materials so that external radiation levels do not exceed regulatory limits. The packaging protects handlers, transporters, and the public from exposure to dose rates in excess of recognized safe limits. Regulations in 10 CFR 71.47 and 49 CFR 173.441 prescribe the external radiation standards for all packages. For shipments to the repository, the limiting radiation dose limit would be 10 millirem per hour at any point 2 meters (6.6 feet) from the outer edge of the railcar or truck trailer.

H.2.2 MARKING, LABELING, AND PLACARDING

U.S. Department of Transportation regulations in 49 CFR require that shippers meet specific hazard communication requirements in marking and labeling packages that contain radioactive materials and other hazardous materials. Markings, labels, and placards identify the hazardous contents to emergency responders in the event of an incident.

Markings provide the proper shipping name, a four-digit hazardous materials number, the shipper's name and address, gross weight, and type of packaging; other important information labels on opposite sides of a package identify the contents and radioactivity level. Shippers of radioactive materials use one of three labels—Radioactive White I, Yellow II, or Yellow III—as shown in Figure H-1. The use of a particular label is based on the radiation level at the surface of the package and the transport index. The *transport* *index*, determined in accordance with 49 CFR 173.403, is a number on the label of a package that indicates the degree of control the carrier must exercise during shipment. Packaging that previously contained Class 7 (radioactive) materials and has been emptied of its contents as much as practicable is exempted from marking requirements. However, 49 CFR 173.428 requires the application of an Empty label (not shown) to the cask.

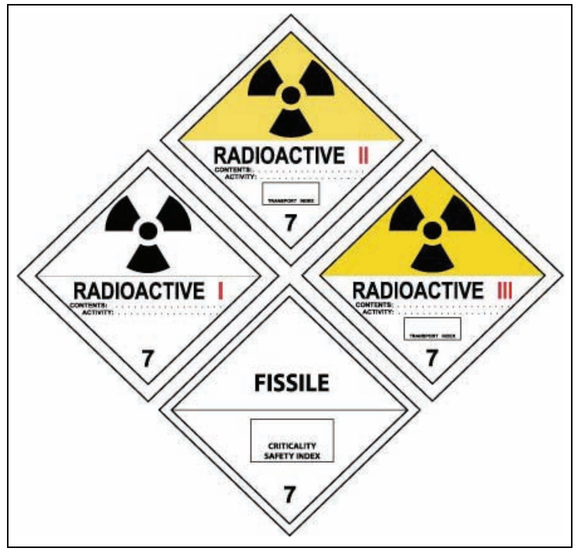


Figure H-1. Radioactive material shipment labels.

Figure H-1 also shows a Fissile label, which shippers must apply to each package with fissile material (a material that is capable of sustaining a chain reaction of nuclear fission). Such labels, where applicable, must be affixed adjacent to the labels for radioactive materials. The Fissile label includes the Criticality Safety Index, which indicates how many fissile packages can be grouped together on a conveyance.

Shipments of spent nuclear fuel and high-level radioactive waste are usually classified as Highway Route-Controlled Quantities of Radioactive Materials, and 49 CFR 172.403(c) requires Radioactive Yellow-III labels for them regardless of the radiation dose rate. For Radioactive Yellow III shipments, 49 CFR 172.504 requires radioactive hazard communication placards (Figure H-2) on each side and each end of a freight container, transport vehicle, or railcar. In addition, for Highway Route-Controlled Quantities of Radioactive Materials shipments the placard must be on a white square background with a black border (49 CFR 172.507 through 172.527). In addition to the placard, a vehicle might have a United Nations Identification Number near the placard. The United Nations assigns these four-digit numbers, which shippers commonly use throughout the world to aid in the quick identification of materials in bulk containers. The number appears on either an orange plane or on a plain white square-on-point configuration similar to a placard. The usual identification number for spent nuclear fuel is UN3328.

Figure H-2. Radioactive hazard communication placard.

H.2.3 SHIPPING PAPERS

The shipper prepares shipping papers and gives them to the carrier. These documents contain additional details about the cargo and include a signed certification that the material is properly classified and in proper condition for transport. Shipping papers also contain emergency information that includes contacts and telephone numbers. Highway carriers must keep shipping papers readily available during transport for inspection by appropriate officials such as state or federal inspectors.

H.2.4 ROUTING

U.S. Department of Transportation regulations classify spent nuclear fuel and high-level radioactive waste as Highway Route-Controlled Quantities of Radioactive Materials shipments. Carriers of these materials are required to use *preferred routes*, which include interstate highway systems or alternative routes selected by state or tribal routing authorities in accordance with U.S. Department of Transportation regulations. Preferred routes generally use beltways and bypasses around cities to avoid highly populated urban centers.

States and tribes can designate alternative preferred routes by following U.S. Department of Transportation regulations for designation and performing a comparative route analysis that adequately considers overall risk to the public. Factors for the analysis can include accident rates, traffic counts, distance, vehicle speeds, population density, land use, timeliness, and availability of emergency response capabilities. States must also document required consultation with affected neighboring jurisdictions. U.S. Department of Transportation highway routing regulations preempt any conflicting routing requirements that state, local, or tribal governments might issue, such as prohibitions on radioactive waste shipments through local nuclear-free zones.

No federal routing rules govern spent nuclear fuel and high-level radioactive waste shipments by rail. Because railroads are privately owned and operated, route selection would involve discussions between DOE and the chosen railroad companies and other stakeholders. Key factors for selection of rail routes include time and distance in transit, the track class and capacity, operational input from carriers, and infrastructure capabilities.

The U.S. Department of Homeland Security and U.S. Department of Transportation issued rulemaking proposals in relation to railroad routing for radioactive materials shipments for security purposes on December 21, 2006; Section H.2.9 discusses the proposals.

H.2.5 ADVANCE NOTIFICATION

DOE Manual 460.2-1, *Radioactive Material Transportation Practices* (DIRS 171934-DOE 2002, all), which implements DOE Order 460.1B, *Packaging and Transportation Safety* and NRC regulations (10 CFR 71.97 and 73.37), requires written notice to governors, or their designees, before shipment of spent nuclear fuel and high-level radioactive waste through their states. If sent by regular mail, the notice must be postmarked at least 7 days before the shipment; for messenger service, it must arrive 4 days before. The notification must contain the name, address, and telephone number of the shipper, the carrier, and the receiver; a description of the shipment; a list of the routes within the state; the estimated date and time of departure from the point of origin; the estimated date and time of entry into the state; and a statement on safeguarding schedule information. Federal regulations allow states to release certain advance information to local officials on a need-to-know basis. As required by Section 180 of the NWPA, all shipments to a repository would comply with NRC regulations on advance notification of state and local governments. In the event of a change in schedule that differs more than 6 hours from what was in the notification to the governor or their designee, DOE would provide the state with the new schedule by telephone. Although current regulations do not require notification of tribal authorities, DOE policy is to inform tribes of spent nuclear fuel and high-level radioactive waste shipments that would pass through their jurisdictions (DIRS 171934-DOE 2002, p. 23).

NRC issued an Advance Notice of Proposed Rulemaking (64 FR 71331) on December 21, 1999, to invite early input from affected parties and the public on advance notification to American Indian tribes of spent nuclear fuel and high-level waste shipments. Although the Commission approved a rulemaking plan, it put the rulemaking on hold pending review of Commission rules in response to the events of September 11, 2001. NRC is coordinating the schedule for this rulemaking with other security rulemaking activities. The current schedule would result in a proposed rule in about 2010.

H.2.6 RAILROAD SAFETY PROGRAM

The *Rail Safety Act of 1970* (Public Law 91-458) authorized states to work with the Federal Railroad Administration to enforce federal railroad safety regulations. States can enforce federal standards for track, signal and train control, motive power and equipment, and operating practices. In 1992, the State Safety Participation regulations (49 CFR Part 212) were revised to permit states to perform hazardous materials inspections of rail shipments. The Grade Crossing Signal System Safety regulations (49 CFR Part 234) were revised to authorize federal and state signal inspectors to ensure that railroad owners or operators were properly testing, inspecting, and maintaining automated warning devices at grade crossings. Before state participation can begin, each state agency must enter into a multiyear agreement with the Federal Railroad Administration for the exercise of specified authority. This agreement can delegate investigative and surveillance authority in relation to all or any part of federal railroad safety laws.

H.2.7 PERSONNEL TRAINING

U.S. Department of Transportation regulations require proper training for anyone involved in the preparation or transportation of hazardous materials, including radioactive materials. In accordance with 49 CFR Part 397, Subpart D, operators of vehicles that transport Highway Route-Controlled Quantities of Radioactive Materials receive special training that covers the properties and hazards of the materials, associated regulations, and applicable emergency procedures. In addition, DOE Orders require that driver or crew training covers operation of the specific package tie-down systems, cask recovery procedures, use of radiation detection instruments, use of satellite tracking systems and other communications equipment, adverse weather and safe parking procedures, public affairs awareness, first responder awareness (29 CFR 1910.120 [q]), and radiation worker “B” (or equivalent) training.

The U.S. Department of Transportation also requires training specific to the mode of transportation. Highway carriers are responsible for the development and maintenance of a qualification and training program that meets Department of Transportation requirements. Rail carriers must comply with Federal Railroad Administration regulations. Rail carriers are responsible for training and qualification of their crews, which includes application of 49 CFR Part 240 for locomotive engineer certification. If DOE decided to provide federal rail crews for waste shipments on the national rail system, the carriers would require a pilot, who would be an engineer familiar with the rail territory, unless the federal engineer was qualified on that route. The Federal Railroad Administration requires recurrent and function-specific training for personnel who perform specific work, such as train crews, dispatchers, and signal maintainers. In addition, the regulations require that each employee receives training that specifically addresses the job function.

H.2.8 OTHER REQUIREMENTS

Organizations that represent different transportation modes often establish mode-specific standards. For example, all North American shipments by rail that change carriers must meet Association of American

Railroads interchange rules. Equipment in interchanges must also meet the requirements of the *Association of American Railroads Field Manual of the A.A.R. Interchange Rules* (DIRS 175727-AAR 2005, all).

On May 1, 2003, the Association released Standard S-2043, *Performance Specification for Trains Used To Carry High-Level Radioactive Material* (DIRS 166338-AAR 2003, all) to establish performance guidelines and specifications for trains that carry spent nuclear fuel or high-level radioactive waste. These guidelines apply to the individual railcars within the train, and they promote communication between railroads, spent nuclear fuel and high-level radioactive waste shippers, and railcar suppliers. The objectives of this standard are (1) to provide a cask, railcar, and train system that ensures safe transportation of casks in the railroad operating environment and allows timetable speeds with limited restrictions and (2) to use the best available technology to minimize the chances of derailment in transportation. This standard reflects the current technical understanding of the railroad industry in relation to optimum vehicle performance through application of current and prospective new railcar technologies. On December 20, 2005, the Association adopted two appendixes to AAR S-2043: Appendix A, "Maintenance Standards and Recommended Practices for Trains Used To Carry High-Level Radioactive Material," and Appendix B, "Operating Standard for Trains Used To Carry High-Level Radioactive Material" (DIRS 166338-AAR 2003, all). Changes and additions to this standard can be expected as specific vehicles are developed. All future changes will be based on the achievement of optimum performance within acceptable expectations for safe operations.

Association of American Railroads Circular No. OT-55-I, *Recommended Railroad Operating Practices for Transportation of Hazardous Materials* (DIRS 183011-AAR 2006, all), provides recommendations on operating practices that are adopted by Association of American Railroads and American Short Line and Regional Railroad Association members in the United States for these shipments. The current revision of the circular became effective July 17, 2006; its recommendations cover road operating practices, yard operating practices, storage and separation distances, transportation community awareness and emergency response program implementation, criteria for shipper notification, time-sensitive materials, and special provisions for spent nuclear fuel and high-level radioactive waste.

The Commercial Vehicle Safety Alliance has developed inspection procedures and out-of-service criteria for commercial highway vehicles that transport shipments of transuranic elements and Highway Route-Controlled Quantities of Radioactive Materials shipments (Section H.4.9). Under these procedures, each state through which a shipment passed would inspect each shipment to the repository, and a shipment would not begin or continue until inspectors determined that the vehicle and its cargo were free of defects.

Trucks that carry spent nuclear fuel or high-level radioactive waste and weigh over 36,300 kilograms (80,000 pounds) would exceed federal commercial vehicle weight limits for nondivisible loads (which cannot be separated into smaller loads). Most states require transportation companies to obtain permits when their vehicles exceed weight limits to control time and place of movement. Local jurisdictions also often require overweight permits. The criteria for the permitting process are not uniform among different jurisdictions. A number of factors affect issuance of these permits including traffic volumes and patterns, protection of state highways and structures such as bridges, zoning and general characteristics of the route, and safety of the motoring public.

H.2.9 PROPOSED RAIL REGULATIONS

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration, in consultation with the Federal Railroad Administration, has proposed revision of the current requirements in the Hazardous Materials Regulations applicable to the safe and secure transportation of hazardous materials by rail at 49 CFR Parts 172 and 174 (71 FR 76834; December 21, 2006). The proposed rulemaking includes "Radioactive Materials" and "Class 7- Highway Route-Controlled Quantities of Radioactive Materials." The proposal would require rail carriers to compile annual data on specified shipments of hazardous materials, to use the data to analyze safety and security risks along rail transportation routes where those materials are transported, to assess alternative routes, and to make routing decisions based on those assessments. The Pipeline and Hazardous Materials Safety Administration has also proposed clarifications of the current security plan requirements to address en route storage, delays in transit, delivery notification, and additional security inspection requirements for hazardous materials shipments.

The Transportation Security Administration has proposed new security requirements for 49 CFR Parts 1520 and 1580 for freight railroad carriers; intercity, commuter, and short-haul passenger train service providers; rail transit systems; and rail operations at certain, fixed-site facilities that ship or receive specified hazardous materials by rail (71 FR 76852; December 21, 2006). The proposal would codify the scope of the existing inspection program and require regulated parties to allow Transportation Safety Administration and Department of Homeland Security officials to enter, inspect, and test property, facilities, and records relevant to rail security. This proposed rule would also require regulated parties to designate rail security coordinators and to report significant security concerns to the Department of Homeland Security.

In addition, the Transportation Security Administration has proposed that freight rail carriers and certain facilities that handle hazardous materials be able, on request, to report location and shipping information to the Administration and that they should implement chain-of-custody requirements to ensure a positive and secure exchange of specified hazardous materials (71 FR 76852, December 21, 2006). The proposal would clarify and extend the sensitive security information protections to cover certain information associated with rail transportation.

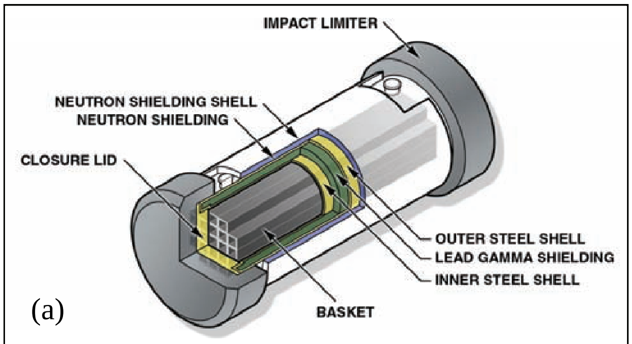
H.3 Transportation System Components

The DOE transportation system would consist of hardware (shipping containers, handling equipment, railcars, and truck trailers), a transportation operations center, a Cask Maintenance Facility, and the Nevada rail line.

H.3.1 SHIPPING CONTAINERS

As required by the NWPA, the designs of the shipping casks for transportation of the spent nuclear fuel and high-level radioactive waste would be NRC-certified. The casks would be sealed containers that could weigh up to 180 metric tons (200 tons). The casks would consist of layers of steel and lead or other materials, which would provide shielding against the radiation from the waste and prevent the materials from escaping to the environment in the event of an incident.

The open end of the cylindrical cask would be sealed with a heavy lid. Impact limiters on each end of the cask would absorb most of the impact force and provide protection of the container and its contents in the event of an incident. Figure H-3 illustrates generic rail and truck casks.



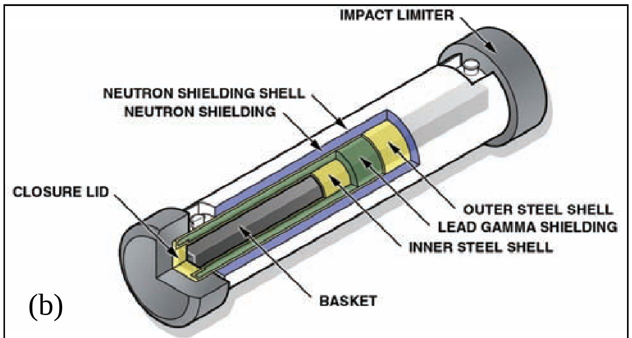


Figure H-3. Generic rail cask (a) and truck cask (b) for spent fuel.

DOE would procure NRC-certified casks from private industry. As required by Section 137 of the NWPA, DOE would use private industry to the fullest extent possible for each aspect of transportation. The Department has a preference for maximizing the use of existing cask designs rather than developing new ones. Existing cask designs would have to be modified to accommodate TAD canisters before NRC certification.

H.3.2 RAILCARS

The trains DOE would use to transport spent nuclear fuel and high-level radioactive waste to the repository would typically use locomotives, escort cars, one or more loaded cask railcars, and buffer railcars that would separate the cask railcars from occupied locomotives and escort railcars.

H.3.3 TRANSPORTATION OPERATIONS CENTER

The functions of a transportation operations center would include coordination between shipping sites and the repository, planning and scheduling of shipments, coordination with carriers, notifications to states and American Indian tribes, monitoring and tracking of shipments, en route communications, emergency management, and security coordination.

H.3.4 CASK MAINTENANCE FACILITY

Owners of rail and highway transportation casks and the associated equipment (for example, personnel barriers and impact limiters) must maintain them in proper condition to satisfy the requirements in their NRC certificates of compliance. The Cask Maintenance Facility would periodically remove casks from service and perform maintenance and inspection. The activities at the Cask Maintenance Facility would include but not be limited to testing, repair, minor decontamination, and approved modifications. The Cask Maintenance Facility would also serve as the primary recordkeeping facility for the cask fleet equipment.

H.3.5 TRANSPORT SERVICES

The U.S. freight railroad system consists of seven Class 1 railroads (mainline), 31 regional railroads, and over 500 local railroads (line-haul railroads smaller than regional railroads). Some origin sites of spent nuclear fuel and high-level radioactive waste have rail services, while others do not. DOE would use short-line or Class 1 railroads to transport casks from the origin sites. There are numerous short-line railroads that operate one or more relatively small sections of track that connect to the Class 1 rail network. Origin sites without rail service would require alternative intermodal delivery from the origin site to a nearby rail transfer facility, either by barge using a nearby dock or by heavy-haul truck using local highways.

At some sites with limited cask handling capability, DOE could use overweight trucks for smaller casks. After loading and preparation, DOE would pick up the cask and deliver it directly to the repository using the public highway network.

DOE would construct a branch rail line to transport casks from a Union Pacific mainline railroad in Nevada to the repository site, and the Department would contract the operation and maintenance of the branch rail line.

H.4 Operational Practices

DOE has adopted as policy the practices that were developed in consultation with stakeholders and are outlined in DOE Manual 460.2-1 (DIRS 171934-DOE 2002, all). The Manual establishes 14 standard transportation practices for Departmental programs to use in the planning and execution of shipments of radioactive materials including radioactive waste. It provides a standardized process and framework for planning and for interacting with state and tribal authorities and transportation contractors and carriers.

H.4.1 STAKEHOLDER INTERACTIONS

The *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all) guides state and tribal government interactions, some of which are already under way. During planning and actual transportation operations, stakeholders are and would be involved in planning for route identification, funding approaches for emergency response planning and training, understanding safeguards and security requirements, operational practices, communications, and information access.

DOE is working collaboratively with states through State Regional Group committees, whose members are state officials responsible for transportation policy, law enforcement, emergency response, and oversight of hazardous materials shipments, and with American Indian tribal governments to assist them to prepare for the shipments.

In addition to coordination with State Regional Groups and tribal governments, a national cooperative effort is underway as part of the Transportation External Coordination Working Group, which involves a broad range of stakeholder organizations that routinely interact with DOE to provide input and recommendations on transportation planning and program information. DOE works with states, tribes, and industry to guide and focus emergency training, coordination with local officials, and other activities to prepare for shipments to the repository.

DOE is preparing a comprehensive national spent fuel transportation plan that accommodates stakeholder concerns to the extent practicable. The plan will outline the challenges and strategies for the development and implementation of the system required to transport the waste to Yucca Mountain.

H.4.2 ROUTE PLANNING PROCESS

An initial step in the planning process to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain is to identify a national suite of routes, both rail and highway. Stakeholder groups in the DOE program are participating in this process by examining potential routing criteria in the route identification process. State Regional Groups, tribal governments, transportation associations, industry, federal agencies, and local government organizations are some of the groups that work collaboratively with DOE in this process. DOE is performing and would perform the work through a Topic Group of the Transportation External Coordination Working Group, which would seek broader public input and collect comments on routing criteria and the process for development of a set of routes. The process includes consideration of industry practices, DOE requirements, and analysis of regional routes that states have previously evaluated in the process to identify a preliminary set of routes. Public involvement is an essential element of a safe, efficient, and flexible transportation system.

H.4.3 PLANNING AND MOBILIZATION

DOE would use the methods and requirements this section describes to establish the baseline operational organization and practices for route identification, fleet planning and acquisition, carrier interactions, and operations.

DOE would develop a Transportation Operations Plan to provide the basis for planning shipments. This plan would describe the operational strategy and delineate the steps to ensure compliance with applicable regulatory and DOE requirements. It would include information on organizational roles and responsibilities, shipment materials, projected shipping windows, estimated numbers of shipments, carriers, packages, sets of routes, prenotification procedures, safe parking arrangements, tracking systems, security arrangements, public information, and emergency preparedness, response, and recovery.

The Department would develop individual site plans to include the information necessary to ship from specific sites that included roles and responsibilities of the participants in the shipping campaign, shipment materials, schedules, number of shipments, types and number of casks and other equipment, carriers, routes, in-transit security arrangements, safe parking arrangements for rail and truck shipments, communications including prenotification, public information, tracking, contingency planning, and emergency preparedness, response, and recovery.

In addition, DOE would issue an Annual Shipment Projection at least 6 months to a year in advance of the beginning of a shipment year and would identify the sites from which it would ship spent nuclear fuel and high-level radioactive waste in a given calendar year, the expected characteristics and quantities of waste to be delivered by each site, types of casks, and anticipated numbers of casks and shipments. The Annual Shipment Projection would not define specific shipment schedules or routes, but DOE would use it for schedule and route planning.

H.4.4 DEDICATED TRAIN SERVICE POLICY

On July 18, 2005, in a policy statement (DIRS 182833-Golan 2005, all), DOE decided that dedicated train service would be the usual manner of rail shipment of commercial and most DOE spent nuclear fuel and high-level radioactive waste to Yucca Mountain. *Dedicated* indicates train service for one commodity (in this case, spent nuclear fuel and high-level radioactive waste). Past and current shipping campaigns have used dedicated train service to address issues of safety, security, cost, and operations. Analyses indicate that the primary benefit of dedicated train service would be significant cost savings over the lifetime of transportation operations. The added cost of dedicated train service would be offset by reductions in fleet size and its attendant operations and maintenance costs. In addition, the shorter times in transit and shorter layovers at switching yards would enhance safety and security. Use of dedicated train service would provide greater operational flexibility and efficiency because of the reduced transit time and greater predictability in routing and scheduling.

H.4.5 TRACKING AND COMMUNICATION

DOE would provide authorized state and tribal governments with the capability and training to monitor shipments to the repository through their jurisdictions using a satellite tracking system, such as the Transportation Tracking and Communication System, that would provide continuous, centralized monitoring and communications capability (DIRS 172433-DOE 2003, p. 5). Trained personnel could use such a system to monitor shipment progress and communicate with the dispatch center. A transportation operations center would be in contact with the carriers and the escorts throughout each shipment. In addition, all truck and rail escort cars would have communications equipment. The train control center would manage rail communications and signaling on the branch Nevada rail line.

DOE would develop detailed backup procedures to ensure safe operations in the event that the tracking system was temporarily unavailable. The procedures would be based on a telephone call-in system for operators to report shipment locations to DOE on a regular basis and before crossing state and tribal borders.

H.4.6 TRANSPORTATION OPERATIONAL CONTINGENCIES

DOE would obtain weather forecasts along routes as part of preshipment planning, notification, and dispatching. At the time of departure, current weather conditions, the weather forecast, and expected travel conditions would have to be acceptable for safe operations. If these conditions were not acceptable, DOE could delay the shipment until travel conditions became acceptable or reroute the shipment.

Shipments would not travel during severe weather or other adverse conditions that could make travel hazardous. DOE would obtain route conditions and construction information that could temporarily affect the planned route through consultation with the railroads and states along the planned route.

DOE would receive input from states and tribes on weather conditions through the satellite tracking system known as TRANSCOM, which they would also use to monitor shipments. Rail carriers use train control and monitoring systems to identify the locations of trains and to make informed decisions to avoid or minimize potentially adverse weather or track conditions. Truck dispatch centers and the transportation operations center would coordinate on weather conditions while shipments were en route.

Continuous communications with a transportation operations center would provide advance warning of potential adverse conditions along the route. If the shipment encountered unanticipated severe weather, the operators would contact this center to coordinate routing to a safe stopping area if it became necessary to delay the shipment until conditions improved.

H.4.7 CARRIER PERSONNEL QUALIFICATIONS

Carriers would develop and maintain qualification and training programs that met U.S. Department of Transportation requirements for drivers, operators, and security personnel. For truck drivers, qualifications include being at least 21 years of age, meeting physical standards, having a commercial driver's license, and successfully completing a road driving test in the shipment vehicle. In addition, drivers must have training on the properties and hazards of the shipment materials as well as the procedures to follow in the event of an emergency. Locomotive engineers must meet the Locomotive Engineer Certification requirements of 49 CFR Part 240, which include completion of an approved training program (Section H.2.7 addresses other training requirements).

H.4.8 NOTICE OF SHIPMENTS

The NRC requires advance notice, en route status, and other pertinent shipment information on DOE shipments (10 CFR Parts 71 and 73). Section H.2.5 addresses advance notification requirements. DOE and other stakeholders would use this information to support coordination of repository receipt operations, to support emergency response capabilities, to identify weather or road conditions that could affect shipments, to identify safe stopping locations, to schedule inspections, and to coordinate appropriate public information programs.

H.4.9 INSPECTIONS

To ensure safety, DOE would inspect shipments when they left their point of origin and when they arrived at the repository to verify vehicle safety and radiological safety of the shipping casks. These inspections would include radiological surveys of radioactive material packages to ensure that they met the radiation level limits of 49 CFR 173.441 and surface contamination limits of 49 CFR 173.443. DOE would inspect rail shipments in accordance with 49 CFR 174.9 and the Federal Railroad Administration High-Level Nuclear Waste Rail Transportation Inspection Policy in Appendix A of *Safety Compliance Oversight Plan for Rail Transportation of High-Level Radioactive Waste and Spent Nuclear Fuel* (DIRS 156703-FRA 1998, all), which includes motive power, signals, track conditions, manifests, and crew credentials. DOE would inspect highway shipments using the enhanced standards of the Commercial Vehicle Safety Alliance, which provide uniform inspection procedures for radiological requirements, drivers, shipping papers, vehicles, and casks (DIRS 175725-CVSA 2005, all).

Although DOE would minimize the number of stops to the extent practicable, under federal regulations states and tribes could order additional inspections when shipments entered their respective jurisdictions. DOE would attempt to coordinate those inspections with normal crew change locations whenever possible.

H.4.10 PROCEDURES FOR OFF-NORMAL CONDITIONS

Off-normal conditions are potentially adverse conditions that do not relate to accidents, incidents, or emergencies. They include but are not limited to mechanical breakdowns, fuel problems, tracking system failure, and illness, injury, or other incapacity of a member of the truck, train, or escort crew. DOE would require carriers to provide operators with specific written procedures that define detailed actions for off-normal events. Procedures would address notifications, deployment of appropriate hazard warnings, security, medical assistance, operator or escort replacement, and maintenance, repair, replacement, or recovery of equipment, as appropriate. Procedures would also cover selection of alternative routes and safe parking areas.

H.4.11 POSTSHIPMENT RADIOLOGICAL SURVEYS

DOE would visually inspect and radiologically survey the external surfaces of a cask after shipment in accordance with U.S. Department of Transportation, DOE, and NRC regulations. Receiving facility operators would survey each cask and transporter on arrival (before unloading) and determine if there was radiological contamination in excess of the applicable limits. The inspections would include the cask, tie-downs, and associated hardware to determine if physical damage occurred during transit.

H.4.12 SHIPMENT OF EMPTY TRANSPORT CASKS

Except before their first use, shipments of all empty transportation casks would comply with the requirements of the NRC certificate of compliance or 49 CFR 173.428, which addresses empty radioactive materials packages, whichever was applicable. DOE would ship casks that did not meet the criteria for “empty” in accordance with the applicable U.S. Department of Transportation hazardous materials regulations. Advance shipment notifications and en route inspections would not apply to the shipment of empty transportation casks; however, DOE would use dedicated train service to realize the cost benefits of a decreased fleet requirement.

H.5 Cask Safety

The purpose of the NRC regulations for transportation of spent nuclear fuel and high-level radioactive waste (10 CFR Part 71) is to protect the public health and safety from normal and off-normal conditions of transport and to safeguard and secure shipments of these materials. Over the years, NRC has amended its regulations to be compatible with the latest editions of the International Atomic Energy Agency and other standards (69 FR 3698, January 26, 2004).

In addition to the standard testing discussed below, NRC has committed to a package performance study for the full-scale testing of a spent nuclear fuel package of the kind DOE would likely use. The Commission approved the proposed test in June 2005 (DIRS 182896-Vietti-Cook 2005, all; DIRS 182897-Reyes 2005, all). According to the proposal, the package would contain surrogate fuel elements and be mounted on a railcar placed at 90 degrees to a simulated rail crossing. The rail package would be subjected to a collision with a locomotive and several freight cars at 96 kilometers (60 miles) per hour. NRC is formulating the study to give the public greater confidence in the movement of spent nuclear fuel, to provide information on the methods and processes of transportation system qualification, and to validate the applicability of NRC regulations.

Regulations in 10 CFR Part 71 require that casks for shipping spent nuclear fuel and high-level radioactive waste must be able to meet specified radiological performance criteria for normal transport and for transport under severe accident conditions. Meeting these requirements is an integral part of the safety assurance process for transportation casks. The ability of a design to withstand these conditions can be demonstrated by comparing designs to similar casks, engineering analyses (such as computer-simulated tests), or by scale-model or full-scale testing. As shown in Figure H-4, these hypothetical accident conditions include, in sequence, a 9-meter (30-foot) drop onto an unyielding flat surface, a 1-meter (40-inch) drop onto a vertical steel bar, exposure of the entire package to fire for 30 minutes, and

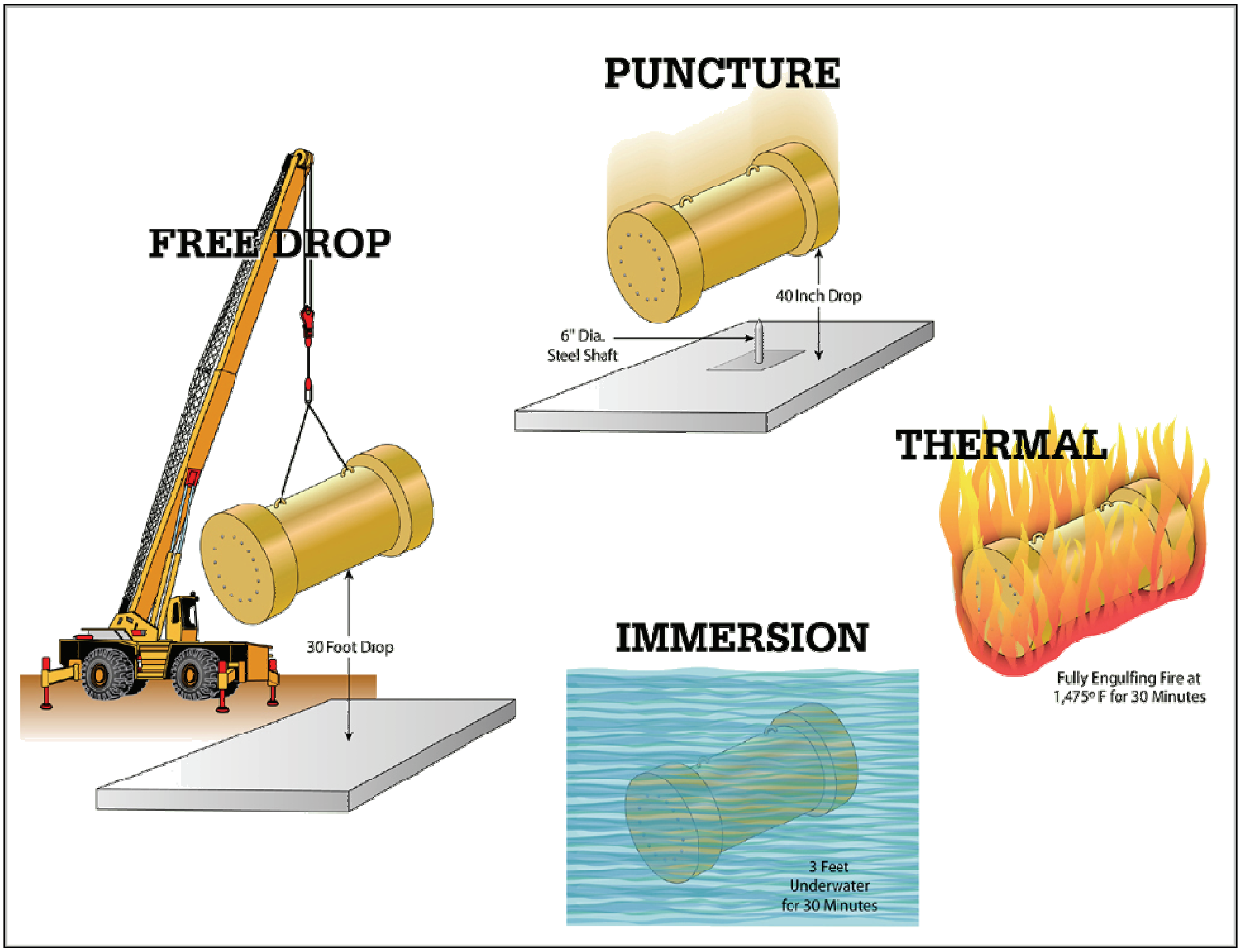


Figure H-4. Hypothetical accident conditions.

immersion in 0.9 meter (3 feet) of water. In addition, an undamaged cask must be able to survive submersion in the equivalent pressure of 15 and 200 meters (50 and 650 feet) of water.

For most accidents more severe than those the hypothetical accident conditions simulate, NRC studies (DIRS 152476-Sprung et al. 2000, all; DIRS 181841-Adkins et al. 2007, all; DIRS 182014-Adkins et al. 2006, all) show that the radiological criteria for containment, shielding, and subcriticality would still be satisfied. The studies also show that for the few severe incidents in which these criteria could be exceeded, only containment and shielding would be affected, and the regulatory criteria could be exceeded only slightly. Based on the analyses of the *Final Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DIRS 155970-DOE 2002, all), casks would continue to contain spent nuclear fuel and high-level radioactive waste fully in more than 99.99 percent of all incidents (of the thousands of shipments over the last 30 years, none has resulted in an injury due to the release of radioactive materials). The following sections discuss each of these packaging performance criteria.

H.5.1 NINE-METER DROP ONTO AN UNYIELDING SURFACE

The first set of accident conditions in the sequence simulates impact and evaluation of a 9-meter (30-foot) free fall onto an unyielding surface with the cask striking the target in the most damaging orientation.

The free fall results in a final velocity of 48 kilometers (30 miles) per hour. Although this velocity is less than the expected speed of interstate highway traffic, it is severe because the target surface is unyielding. This results in the cask absorbing all the energy of the drop, which is approximately equivalent to a 96-kilometer (60-mile)-per-hour impact with a medium hardness surface (such as shale or other relatively soft rock) and a 150-kilometer (90-mile)-per-hour impact with a soft surface (such as tillable soil).

H.5.2 ONE-METER DROP ONTO A STEEL BAR

The second set of accident conditions simulates a cask hitting a rod or bar-like object that could be present in an accident. This requires evaluation for a 1-meter (40-inch) drop onto a 15-centimeter (6-inch)-diameter rod on an unyielding surface. The cask must be in the orientation in which maximum damage would be likely. In addition, the bar must be long enough to cause maximum damage to the cask. This evaluates several impacts in which different parts of a cask strike the bar either by simulation or physical testing.

H.5.3 FIRE

The third set of accident conditions simulates a fire that occurs after the two impacts. This involves a hydrocarbon fire with an average flame temperature of 800°C (1,475°F) and requires the cask to be fully engulfed in the flame for 30 minutes.

H.5.4 WATER IMMERSION

The final set of accident conditions in the sequence is shallow immersion. The cask must be immersed in 0.9 meter (3 feet) of water. The purpose of this test is to ensure that water cannot leak into the cask after having passed through the challenges.

An undamaged version of the cask must also be able to survive immersion in the equivalent of 15 meters (50 feet) of water at a pressure of about 1,500 grams per square centimeter (22 pounds per square inch) to test for leakage. Furthermore, shipping casks for more than 1 million curies of radioactivity must be able to survive water pressure of about 20,000 grams per square centimeter (290 pounds per square inch) for 1 hour without collapsing, buckling, or leaking. That pressure is equivalent to a depth of about 200 meters (650 feet).

H.5.5 ACCEPTANCE CRITERIA

To be judged successful in meeting all but the 200-meter (650-foot) submersion requirement, a cask must not release more than limited amounts of radioactive material in 1 week. These release limits are set for each radionuclide based on dispersivity and toxicity. In addition, the cask must not emit radiation at a dose rate of greater than 1 rem per hour at a distance of 1 meter (3.3 feet) from the cask surface. Last, the contents of the cask must not be capable of undergoing a nuclear chain reaction, or criticality, as a result of the hypothetical accident conditions.

H.5.6 USE OF MODELS

Manufacturers can demonstrate the ability of a cask to survive these hypothetical accident conditions in several ways. They can subject a full-size model of the cask to the sequences, use smaller models of the casks (typically half- or quarter-scale), compare the cask design to previously licensed designs, or analyze the hypothetical accident scenarios with computer models. NRC approves what level of physical testing or analysis is necessary for each cask design. Because NRC generally accepts the results of scale-model testing, more expensive full-scale testing rarely occurs, although NRC sometimes requires such tests for specific cask components. For example, NRC could accept quarter-scale drop tests for a particular cask design but full-scale tests of the cask's impact limiters. Computer analysis could be sufficient for meeting the hypothetical fire and criticality control criteria.

H.6 Emergency Response

H.6.1 ROLES AND RESPONSIBILITIES

States and tribes along shipping routes have the primary responsibility for the protection of the public and environment in their jurisdictions. If an emergency that involved a DOE radioactive materials shipment occurred, incident command would be established based on the procedures and policies of the state, tribe, or local jurisdiction. When requested by civil authorities, DOE would provide technical advice and assistance including access to teams of experts in radiological monitoring and related technical areas. DOE staffs eight Regional Coordinating Offices 24 hours a day, 365 days a year with teams of nuclear engineers, health physicists, industrial hygienists, public affairs specialists, and other professionals (Section H.6.2 contains further detail on the DOE role). Under NWPA Section 180(c), DOE must provide technical assistance and funds to states for training for public safety officials of appropriate units of local government and American Indian tribes through whose jurisdiction DOE plans to transport spent nuclear fuel or high-level radioactive waste. Training must cover procedures for safe routine transportation of these materials as well as for emergency response situations.

DOE would require selected carriers to provide drivers and train crews with specific written procedures that defined detailed actions for an emergency or incident that involved property damage, injury, or the release or potential release of radioactive materials. Procedures would comply with U.S. Department of Transportation guidelines for emergency response in the 2004 *Emergency Response Guidebook* (DIRS 175728-DOT 2004, all) and would address emergency assistance to injured crew or others who were involved in identification and assessment of the situation, notification and communication requirements, securing of the site and controlling access, and technical help to first responders.

H.6.2 FEDERAL COORDINATION

The Department of Homeland Security coordinates the overall Federal Government response to radiological Incidents of National Significance in accordance with Homeland Security Presidential Directive 5 (DIRS 182271-DHS 2003, all) and the *National Response Plan* (DIRS 175729-DHS 2004, all). Based on Directive 5 criteria, an Incident of National Significance is an actual or potential high-impact event that requires a coordinated and effective response by, and appropriate combination of, federal, state, local, tribal, nongovernmental, or private-sector entities to save lives and minimize damage, and to provide the basis for long-term community recovery and mitigation activities.

In Directive 5, the President designates the Secretary of Homeland Security as the Principal Federal Official for domestic incident management and empowers the Secretary to coordinate federal resources used in response to terrorist attacks, major disasters, or other emergencies in specific cases (DIRS 182271-DHS 2003, all). The Directive establishes a single, comprehensive National Incident Management System that unifies federal, state, territorial, tribal, and local lines of government into one coordinated effort. This system encompasses much more than the Incident Command System, which is nonetheless a critical component of the National Incident Management System. That system also provides a common foundation for training and other preparedness efforts, communicating and sharing information with other responders and with the public, ordering resources to assist with a response effort, and integrating new technologies and standards to support incident management. The Incident Command System uses as its base the local first responder protocols; that use does not eliminate the required agreements and coordination among all levels of government.

In Directive 5 (DIRS 182271-DHS 2003, all), the President directed the development of the new *National Response Plan* (DIRS 175729-DHS 2004, all) to align federal coordination structures, capabilities, and resources into a unified approach to domestic incident management. The Plan is built on the template of the National Incident Management System. The Plan provides a comprehensive, all-hazards approach to domestic incident management. All federal departments and agencies must adopt the National Incident Management System and use it in their individual domestic incident management and emergency prevention, preparedness, response, recovery, and mitigation activities, as well as in support of all actions taken to assist state or local entities.

DOE supports the Department of Homeland Security as the coordinating agency for incidents that involve the transportation of radioactive materials by or for DOE. DOE is otherwise responsible for the radioactive material, facility, or activity in the incident. DOE is part of the Unified Command, which is an application of the Incident Command System for when there is more than one agency with incident jurisdiction or when incidents cross political jurisdictions. DOE coordinates the federal radiological response activities as appropriate. Agencies work together through the designated members of the Unified Command, often the senior person from agencies or disciplines that participate in the Unified Command, to establish a common set of objectives and strategies.

DOE, as the transporter of radiological material, would notify state and tribal authorities and the Homeland Security Operations Center. The Department of Homeland Security and DOE coordinate federal response and recovery activities for the radiological aspects of an incident. DOE reports information and intelligence in relation to situational awareness and incident management to the Homeland Security Operations Center.

The Department of Homeland Security and DOE are responsible for coordination of security activities for federal response operations. While spent nuclear fuel and high-level radioactive waste shipments are in transit, state, local, and tribal governments could provide security for a radiological transportation incident that occurred on public lands. The Department of Homeland Security, with DOE as the coordinating agency, approves issuance of all technical data to state, local, and tribal governments.

The Interagency Modeling and Atmospheric Assessment Center, is responsible for production, coordination, and dissemination of consequence predictions for an airborne hazardous material release. The Center generates the single federal prediction of atmospheric dispersions and their consequences using the best available resources.

Federal monitoring and assessment activities are coordinated with state, local, and tribal governments. Federal agency plans and procedures for implementation of this activity are designed to be compatible with the radiological emergency planning requirements for state and local governments, specific facilities, and existing memoranda of understanding and interagency agreements.

DOE maintains national and regional coordination offices at points of access to federal radiological emergency assistance. Requests for Radiological Assessment Program teams go directly to the DOE Emergency Operations Center in Washington, D.C. If the situation requires more assistance than a team can provide, DOE alerts or activates additional resources. DOE can respond with additional resources including the Aerial Measurement System to provide wide-area radiation monitoring and Radiation Emergency Assistance Center/Training Site medical advisory teams. Some participating federal agencies have radiological planning and emergency responsibilities as part of their statutory authority, as well as established working relationships with state counterparts. The monitoring and assessment activity, which DOE coordinates, does not alter these responsibilities but complements them by providing coordination of the initial federal radiological monitoring and assessment response activities.

The U.S. Department of Homeland Security and DOE, as the coordinating agency, oversee the development of Federal Protective Action Recommendations. In this capacity, they provide advice and assistance to state, tribal, and local governments, which can include advice and assistance on measures to avoid or reduce exposure of the public to radiation from a release of radioactive material and advice on emergency actions such as sheltering and evacuation.

State, local, and tribal governments are encouraged to follow closely the *National Response Plan* (DIRS 175729-DHS 2004, all), the Nuclear/Radiological Incident Annex, and the National Incident Management System protocols and procedures. As established, all federal, state, local and tribal responders agree to and follow the Incident Command System.

H.7 Technical Assistance and Funding for Training of State and American Indian Public Safety Officials

The NWPA requires DOE to provide technical assistance and funds to states and American Indian tribes for training public safety officials of appropriate units of local governments through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste. Section 180(c) further provides that training must cover procedures for safe routing and emergency response situations. Section 180(c) encompasses all modes of transportation, and funding would come from the Nuclear Waste Fund. Once implemented, this program would provide funding and technical assistance to train firefighters, law enforcement officers, and other public safety officials in preparation for repository shipments through their jurisdictions.

To implement this requirement in the 1990s, DOE published four Federal Register notices to solicit public comment on its approach to implementing Section 180(c). DOE responded to the comments in subsequent notices through April 1998. In 2004, the changes in homeland security and DOE transportation practices made it timely for DOE to renew efforts to develop Section 180(c) policy and implementation procedures. DOE evaluated changes in emergency preparedness and funding for responders since 1998 as well as emergency preparedness grant programs that began after September 11, 2001. The evaluation considered programs the Department of Homeland Security and the Federal Emergency Management Agency developed and relevant DOE funding and emergency response training efforts such as the Waste Isolation Pilot Plant and Foreign Research Reactor transportation programs.

The revisitation of Section 180(c) implementation began with the formation of a Transportation External Coordination Working Group Topic Group in April 2004. DOE also worked with State Regional Groups and the Tribal Issues Topic Group of the Transportation External Coordination Working Group to solicit stakeholder input on the policy. Topic Group members wrote issue papers on specific Section 180(c) topics such as allowable activities, funding allocation method, timing and eligibility, and definitions. From these materials, DOE developed a draft policy that it issued in a Federal Register notice on July 23, 2007 (72 FR 40139) to request additional comments from stakeholders and the public. DOE plans to conduct a pilot test of the program and then issue the final Section 180(c) policy.

Under the proposed policy, DOE would make two grants available to eligible state and tribal governments. An initial assessment and planning grant would be available about 4 years before shipments through a jurisdiction began. Once the state or tribe completed the assessment and planning grant activities, they would be eligible for the training grant every year that shipments traveled through their jurisdiction.

H.8 Transportation Security

Transportation safeguards and security are among the highest DOE priorities as it plans for shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain. DOE would build the security program for the shipments on the successful security program it developed and has successfully used in past decades for shipments of spent nuclear fuel to DOE facilities from foreign and domestic reactors.

An effective security program must protect members of the public near transportation routes as well as minimize potential threats to workers, and it must include security elements appropriate to each phase of transportation. DOE would continually test security procedures to identify improvements in the security system throughout transportation operations. The key elements of a secure transportation program include physical security systems, information security, materials control and accounting, personnel security, security program management, and emergency response capabilities.

DOE is working closely with other federal agencies including NRC and the Department of Homeland Security to understand and mitigate potential threats to shipments. In addition to domestic efforts, the Department is a member of the International Working Group on Sabotage for Transport and Storage Casks, which investigates the consequences of a potential act of sabotage and explores opportunities to enhance the physical protection of casks. As a result of these efforts, DOE would modify its methods and systems as appropriate between now and the time of shipments.

In coordination with other federal agencies, DOE is working with other stakeholders including state, local, and tribal governments; industry associations such as the Association of American Railroads, and technical advisory and oversight organizations such as the National Academies of Science and the Nuclear Waste Technical Review Board. This enables DOE to take advantage of the experience and practical recommendations of experts on a broad range of security-related technical, procedural, and operational matters.

H.9 Liability

The *Price-Anderson Act* provides indemnification for liability for nuclear incidents that apply to the proposed Yucca Mountain repository. The following sections address specific details or provisions of the Act.

H.9.1 THE PRICE-ANDERSON ACT

In 1957, Congress enacted the *Price-Anderson Act* as an amendment to the *Atomic Energy Act* to encourage the development of a commercial nuclear industry and to ensure prompt and equitable compensation in the event of a nuclear incident. The *Price-Anderson Act* establishes a system of financial protection for persons who could be liable for and persons who could be injured by a nuclear incident. The purposes of the Act are (1) to encourage growth and development of the nuclear industry through the increased participation of private industry and (2) to protect the public by ensuring that funds are available to compensate victims for damages and injuries sustained in the event of a nuclear incident. Congress renewed and amended the indemnification provisions in 1966, 1969, 1975, and 1988. The 1988 *Price-Anderson Amendments Act* extended the Act for 14 years until August 1, 2002 (Public Law 100-408, 102 Stat. 1066). Since then, Congress has extended the Act until December 31, 2025, and increased liability to $10.26 billion for an extraordinary nuclear occurrence (that is, any nuclear incident that causes substantial damage), subject to increase for inflation.

H.9.2 INDEMNIFICATION UNDER THE PRICE-ANDERSON ACT

For each shipper, DOE must include an agreement of indemnification in each contract that involves the risk of a nuclear incident. This indemnification (1) provides omnibus coverage of all persons who could be legally liable, (2) fully indemnifies all legal liability up to the statutory limit on such liability (currently $10.26 billion for a nuclear incident in the United States), (3) covers all DOE contractual activity that could result in a nuclear incident in the United States, (4) is not subject to the usual limitation on the availability of appropriated funds, and (5) is mandatory and exclusive.

H.9.3 COVERED AND EXCLUDED INDEMNIFICATION

The *Price-Anderson Act* indemnifies liability arising out of, or resulting from, a nuclear incident or precautionary evacuation, including all reasonable additional costs incurred by a state or a political subdivision of a state, in the course of responding to a nuclear incident or a precautionary evacuation. It excludes (1) claims under state or federal worker compensation acts of indemnified employees or persons who are at the site of, and in connection with, the activity where the nuclear incident occurs, (2) claims that arise out of an act of war, and (3) claims that involve certain property on the site.

H.9.4 PRICE-ANDERSON ACT DEFINITION OF A NUCLEAR INCIDENT

A nuclear incident is any occurrence, including an extraordinary nuclear occurrence, that causes bodily injury, sickness, disease, death, loss of or damage to property, or loss of use of property, that arises out of or results from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material (42 U.S.C. 2014).

H.9.5 PROVISIONS FOR PRECAUTIONARY EVACUATION

A precautionary evacuation is an evacuation of the public within a specified area near a nuclear facility or the transportation route in the case of an incident that involves transportation of source material, special nuclear material, byproduct material, spent nuclear fuel, high-level radioactive waste, or transuranic waste. It must be the result of an event that is not classified as a nuclear incident but poses an imminent danger of injury or damage from the radiological properties of such nuclear materials and causes an evacuation. The evacuation must be initiated by an official of a state or a political subdivision of a state who is authorized by state law to initiate such an evacuation and who reasonably determined that such an evacuation was necessary to protect the public health and safety.

H.9.6 AMOUNT OF INDEMNIFICATION

The *Price-Anderson Act* establishes a system of private insurance and federal indemnification to ensure compensation for damage or injuries suffered by the public in a nuclear incident. The current amount of $10.26 billion reflects a threshold level beyond which Congress would review the need for additional payment of claims in the case of a nuclear incident with catastrophic damage. The limit for incidents that occur outside the United States is $500 million, and the nuclear material must be owned by, and used by or under contract with, the United States.

H.9.7 INDEMNIFICATION OF TRANSPORTATION ACTIVITIES

DOE indemnifies any nuclear incident that arises in the course of any transportation activities in connection with a DOE contractual activity, including transportation of nuclear materials to and from DOE facilities.

H.9.8 COVERED NUCLEAR WASTE ACTIVITIES

The indemnification specifically includes nuclear waste activities that DOE undertakes in relation to the storage, handling, transportation, treatment, disposal of, or research and development on spent nuclear fuel, high-level radioactive waste, or transuranic waste. It would cover liability for incidents that could occur while wastes were in transit from nuclear power plants, at a storage facility, or at Yucca Mountain. If a DOE contractor or other indemnified person was liable for the nuclear incident or a precautionary evacuation that resulted from its contractual activities, that person would be indemnified for that liability. While DOE tort liability would be determined under the *Federal Tort Claims Act* (28 U.S.C. 1346(b), 1402(b), 2401(b), and 2671 through 2680), the Department would use contractors to transport spent nuclear fuel and high-level radioactive waste and to construct and operate a repository. Moreover, if public liability arose out of activities that the Nuclear Waste Fund supported, the Fund would pay compensation up to the maximum amount of protection. The NWPA established the fund to support federal activities for the disposal of spent nuclear fuel and high-level radioactive waste.

H.9.9 INDEMNIFICATION FOR STATE, AMERICAN INDIAN, AND LOCAL GOVERNMENTS

State, American Indian, and local governments are persons in the sense that they might be indemnified if they incur legal liability. The *Price-Anderson Act* defines a person as including "(1) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, government agency other than [DOE or the Nuclear Regulatory] Commission, any state or any political subdivision of, or any political entity within a state, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (2) any legal successor, representative, agent, or agency of the foregoing" (42 U.S.C. 2214). A state or a political subdivision of a state could be entitled to indemnification for legal liability, which would include all reasonable additional costs of responding to a nuclear incident or an authorized precautionary evacuation. In addition, indemnified persons could include contractors, subcontractors, suppliers, shippers, transporters, emergency response workers, health professional personnel, workers, and victims.

H.9.10 PROCEDURES FOR CLAIMS AND LITIGATION

Numerous provisions ensure the prompt availability and equitable distribution of compensation, which would include emergency assistance payments, consolidation and prioritization of claims in one federal court, channeling of liability to one source of funds, and waiver of certain defenses in the event of a large incident. The *Price-Anderson Act* authorizes payments for immediate assistance after a nuclear incident. In addition, it provides for the establishment of coordinated procedures for the prompt handling, investigation, and settlement of claims that result from a nuclear incident.

H.9.11 FEDERAL JURISDICTION OVER CLAIMS

The U.S. District Court for the district in which a nuclear incident occurred would have original jurisdiction "with respect to any [suit asserting] public liability...without regard to the citizenship of any party or the amount in controversy" [42 U.S.C. 2210(n)]. If a case was brought in another court, it would be removed to the U.S. District Court with jurisdiction upon motion of a defendant, NRC, or DOE.

H.9.12 CHANNELING LIABILITY TO ONE SOURCE OF FUNDS

The *Price-Anderson Act* channels the indemnification (that is, the payment of claims that arise from the legal liability of any person for a nuclear incident) to one source of funds. This *economic channeling* eliminates the need to sue all potential defendants or to allocate legal liability among multiple potential defendants. Economic channeling results from the broad definition of indemnified persons to include any person who could be legally liable for a nuclear incident. Therefore, regardless of individual legal liability for a nuclear incident that resulted from a DOE contractual activity or NRC-licensed activity, the indemnity will pay the claim.

In the hearings on the original Act, "the question of protecting the public was raised where some unusual incident, such as negligence in maintaining an airplane motor, should cause an airplane to crash into a reactor and thereby cause damage to the public. Under this bill, the public is protected and the airplane company can also take advantage of the indemnification and other proceedings" (DIRS 155789-DOE 1999, p. 12).

H.9.13 LEGAL LIABILITY UNDER STATE TORT LAW

The *Price-Anderson Act* does not define legal liability, but the legislative history clearly indicates that state tort law determines the covered legal liabilities (DIRS 155789-DOE 1999, p. A-6). In 1988, *public liability action* was defined to state explicitly that "the substantive rules for decision in such action shall be derived from the law of the state in which the nuclear incident involved occurs, unless such law is inconsistent with the provisions of [Section 2210 of Title 42]" (42 U.S.C. 2014).

H.9.14 PROVISIONS WHERE STATE TORT LAW MAY BE WAIVED

The *Price-Anderson Act* includes provisions to minimize protracted litigation and to eliminate the need to prove the fault of or to allocate legal liability among various potential defendants. Certain provisions of state law may be superseded by uniform rules that the Act prescribes, such as a limitation on punitive damages. In the case of an extraordinary nuclear occurrence, the Act imposes strict liability by requiring the waiver of any defenses in relation to conduct of the claimant or fault of any indemnified person. Such waivers would result, in effect, in strict liability, the elimination of charitable and governmental immunities, and the substitution of a 3-year discovery rule in place of statutes of limitations that would normally bar all suits after a specified number of years.

H.9.15 COVERAGE AVAILABLE FOR INCIDENTS IF THE PRICE-ANDERSON ACT DOES NOT APPLY

If an incident does not involve the actual release of radioactive materials or a precautionary evacuation is not authorized, *Price-Anderson Act* indemnification does not apply. If the indemnification does not apply, liability is determined under state law, as it would be for any other type of transportation incident. Private insurance could apply. As noted above, however, the Act would cover all DOE contracts for transportation of spent nuclear fuel and high-level radioactive waste to a repository for nuclear incidents and precautionary evacuations. Indemnified persons under that DOE contractual activity would include the contractors, subcontractors, suppliers, state, American Indian, and local governments, shippers and transporters, emergency response workers, and all other workers and victims.

Carriers would have private insurance to cover liability from a nonnuclear incident and for environmental restoration for such incidents. The *Motor Carrier Act* (42 U.S.C. 10927) and its implementing regulations (49 CFR Part 387) require all motor vehicles that carry spent nuclear fuel or high-level radioactive waste to maintain financial responsibility of at least $5 million. Federal law does not require rail, barge, or air carriers of radioactive materials to maintain liability coverage, but these carriers often voluntarily cover such insurance. Private insurance policies often exclude coverage of nuclear incidents. Therefore, private insurance policies generally apply only to the extent that the *Price-Anderson Act* is not applicable.

H.10 National Academy of Sciences Findings and Recommendations

In 2006, the National Academy of Sciences Committee on Transportation of Radioactive Waste issued *Going the Distance? The Safe Transport of Spent Nuclear and High-Level Radioactive Waste in the United States* (DIRS 182032-National Research Council 2006, all). The following sections provide the findings and recommendations from this report that are relevant to this Repository SEIS along with a discussion of the DOE position on or approach to the aspects of the findings and recommendations.

H.10.1 TRANSPORTATION SAFETY AND SECURITY

Principal Academy Finding on Transportation Safety

> The committee could identify no fundamental technical barriers to the safe transport of spent nuclear fuel and high-level radioactive waste in the United States. Transport by highway (for small-quantity shipments) and by rail (for large-quantity shipments) is, from a technical viewpoint, a low-radiological-risk activity with manageable safety, health, and environmental consequences when conducted with strict adherence to existing regulations. However, there are a number of social and institutional challenges to the successful initial implementation of large-quantity shipping programs that will require

> expeditious resolution as described in this report. Moreover, the challenges of sustained implementation should not be underestimated.

DOE agrees that the transportation of spent nuclear fuel and high-level radioactive waste has a low radiological risk with manageable safety. DOE also agrees that there are social and institutional challenges, but the Department believes it would meet these challenges successfully through a process that has transportation safety as its priority.

Principal Academy Finding on Transportation Security

> Malevolent acts against spent fuel and high-level waste shipments are a major technical and societal concern, especially following the September 11, 2001, terrorist attacks on the United States. The committee judges that some of its recommendations for improving transportation safety might also enhance transportation security. The Nuclear Regulatory Commission is undertaking a series of security studies, but the committee was unable to perform an in-depth technical examination of transportation security because of information constraints.

Academy Recommendation

> An independent examination of the security of spent fuel and high-level waste transportation should be carried out prior to the commencement of large-quantity shipments to a federal repository or to interim storage. This examination should provide an integrated evaluation of the threat environment, the response of packages to credible malevolent acts, and operational security requirements for protecting spent fuel and high-level waste while in transport. This examination should be carried out by a technically knowledgeable group that is independent of the government and free from institutional and financial conflicts of interest. This group should be given full access to the necessary classified documents and Safeguards Information to carry out this task. The findings and recommendations from this examination should be made available to the public to the fullest extent possible.

Transportation safeguards and security are among DOE's highest priorities as it plans for shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository. The Department would build the security program for the repository shipments on the security program that it has developed and successfully used in past decades for shipments of spent nuclear fuel to DOE facilities from foreign and domestic reactors.

An effective security program must protect members of the public near transportation routes as well as potential threats to workers, and it must include security elements appropriate to each phase of transportation. Continual testing of security procedures would result in improvements in the security system through completion of transportation operations for Yucca Mountain. The most important elements of a secure transportation program include physical security systems, information security, materials control and accounting, personnel security, security program management, and emergency response capabilities.

DOE is working closely with other Federal agencies including the NRC, and the U.S. Department of Homeland Security, and the Transportation Security Agency to understand and eliminate potential threats to repository shipments. In addition to its domestic efforts, the Department is a member of the

International Working Group on Sabotage for Transport and Storage Casks, which is investigating the consequences of a potential act of sabotage and is exploring opportunities to enhance the physical protection of casks. As a result of these efforts, DOE would modify its methods and systems as appropriate between now and the time of shipments.

In coordination with other Federal agencies, DOE is working with other stakeholders including state, tribal, and local governments; industry associations such as the Association of American Railroads and technical advisory and oversight organizations such as the National Academy of Sciences and the Nuclear Waste Technical Review Board. This allows DOE to take advantage of the experience and practical recommendations of experts on a broad range of security-related technical, procedural, and operational matters.

H.10.2 TRANSPORTATION RISK

Academy Finding

There are two types of transportation risk: health and safety risks and social risks. The health and safety risks arise from the potential exposure of transportation workers as well as other people who travel, work, or live near transportation routes to radiation that may be emitted or released from these loaded packages. Social risks arise from social processes and human perceptions and can have both direct socioeconomic impacts and perception-based impacts.

There are two potential sources of radiological exposures from transporting spent fuel and high-level waste: (1) radiation shine from spent fuel and high-level waste transport packages under normal transport conditions; and (2) potential increases in radiation shine and release of radioactive materials from transport packages under accident conditions that are severe enough to compromise fuel element and package integrity. The radiological risks associated with the transportation of spent fuel and high-level waste are well understood and are generally low, with the possible exception of risks from releases in extreme accidents involving very long duration, fully engulfing fires. While the likelihood of such extreme accidents appears to be very small, their occurrence cannot be ruled out based on historical accident data for other types of hazardous material shipments. However, the likelihood of occurrence and consequences can be reduced further through relatively simple operational controls and restrictions and route-specific analyses to identify and mitigate hazards that could lead to such accidents.

Academy Recommendation

To address radiological risk, the NAS stated there were clear transportation operations and safety advantages to be gained from shipping older (i.e. radiologically and thermally cooler) spent fuel first.

Transportation planners and managers should undertake detailed surveys of transportation routes to identify potential hazards that could lead to or exacerbate extreme accidents involving very long duration, fully engulfing fires. Planners and managers should also take steps to avoid or mitigate such hazards before the commencement of shipments or shipping campaigns.

This Repository SEIS evaluated the radiological risks of transportation accidents and found these risks to be very low, as did the Yucca Mountain FEIS. In addition, NRC has evaluated the response of spent nuclear fuel casks to the environments that existed during the Baltimore tunnel fire and the Caldecott tunnel fire, which would be representative of long duration, fully engulfing fires. These evaluations show that releases of radioactive material during these types of events, if they occurred at all, would be very small. Based on recommendations from the NRC, the Association of American Railroads has modified its operating standards to prohibit trains that carry flammable materials from being in a tunnel at the same time as a train that carries spent fuel. This administrative adjustment addresses some of the concerns of the Academy.

An initial step in the planning process to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain repository would be to identify a national suite of rail and highway routes. Stakeholder groups in the DOE transportation program are participating in this process by examining routing criteria that DOE could use in the route identification process. State Regional Groups, American Indian tribes, transportation associations, industry, Federal agencies, and local government organizations are some of the groups that work collaboratively with DOE in this process.

Academy Finding

> The social risks for spent fuel and high-level waste transportation pose important challenges to the successful implementation of programs for transporting spent fuel and high-level waste in the United States. Such risks have received substantially less attention than health and safety risks, and some are difficult to characterize. Current research and practice suggest that transportation planners and managers can take early proactive steps to characterize, communicate, and manage the social risks that arise from their operations. Such steps may have additional benefits: they may increase the openness and transparency of transportation planning and programs; build community capacity to mitigate these risks; and possibly increase trust and confidence in transportation programs.

Academy Recommendation

> Transportation implementers should take early and proactive steps to establish formal mechanisms for gathering high-quality and diverse advice about social risks and their management on an ongoing basis. The committee makes two recommendations for the establishment of such mechanisms for the Department of Energy’s program to transport spent fuel and high-level waste to a federal repository at Yucca Mountain: (1) expand the membership and scope of an existing advisory group (Transportation External Coordination Working Group; see Chapter 5) to obtain outside advice on social risk, including impacts and management; and (2) establish a transportation risk advisory group that is explicitly designed to provide advice on characterizing, communicating, and mitigating the social, security, and health and safety risks that arise from the transportation of spent fuel and high-level waste to a federal repository or interim storage. This group should be comprised of risk experts and practitioners drawn from the relevant technical and social science disciplines and should be convened under the Federal Advisory Committee Act or a similar arrangement to enhance the openness of its operations. Its members should receive security clearances to facilitate access to appropriate transportation security information. The existing federal Nuclear Waste Technical Review Board, which will cease operations no later than one year after the

Department of Energy begins disposal of spent fuel or high-level waste in a repository, could be broadened to serve this function.

DOE has reviewed the Academy recommendation on involving social scientists in the Transportation External Coordination Working Group and on expert panels, and the Department has contacted some panel members to explore opportunities for future studies. DOE has sponsored studies by social scientists in the past on risk perception about transportation of radioactive materials and adjusted its programs to focus on local officials and support for emergency planning and training as a result. The Department needs to update this study and is in the process of reviewing literature to understand gaps in research to address some of the most pressing transportation issues. In addition, DOE has proposed a topic group within the Transportation External Coordination Working Group to address social risks. The Working Group membership has not yet indicated if that is an area they want to focus on at this time.

H.10.3 CURRENT CONCERNS ABOUT TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

H.10.3.1 *Package Performance*

Academy Finding

Transportation packages play a crucial role in the safety of spent fuel and high-level radioactive waste shipments by providing a robust barrier to the release of radiation and radioactive material under both normal transport and accident conditions. International Atomic Energy Agency package performance standards and associated Nuclear Regulatory Commission regulations are adequate to ensure package containment effectiveness over a wide range of transport conditions, including most credible accident conditions. However, recently published work suggests that extreme accident scenarios involving very long duration, fully engulfing fires might produce thermal loading conditions sufficient to compromise containment effectiveness. The consequences of such thermal loading conditions for containment effectiveness are the subject of ongoing investigations by the Nuclear Regulatory Commission and other parties, and this work is improving the understanding of package performance. Nonetheless, additional analyses and experimentation are needed to demonstrate a bounding-level understanding of package performance in response to very long duration, fully engulfing fires for a representative set of package designs.

Academy Recommendation

The Nuclear Regulatory Commission should build on recent progress in understanding package performance in very long duration fires. To this end, the agency should undertake additional analyses of very long duration fire scenarios that bound expected real world accident conditions for a representative set of package designs that are likely to be used in future large-quantity shipping programs. The objectives of these analyses should be to:

- Understand the performance of package barriers (spent fuel cladding and package seals);

- Estimate the potential quantities and consequences of any releases of radioactive material; and

- Examine the need for regulatory changes (e.g., package testing requirements) or operational changes (e.g., restrictions on trains carrying spent fuel) either to help prevent accidents that could lead to such fire conditions or to mitigate their consequences.

Strong consideration should also be given to performing well-instrumented tests for improving and validating the computer models used for carrying out these analyses, perhaps as part of the full-scale test planned by the Nuclear Regulatory Commission for its package performance study. Based on the results of these investigations, the Commission should implement operational controls and restrictions on spent fuel and high-level radioactive waste shipments as necessary to reduce the chances that such fire conditions might be encountered in service. Such effective steps might include, for example, additional operational restrictions on trains carrying spent fuel and high-level radioactive waste to prevent co-location with trains carrying flammable materials in tunnels, in rail yards, and on sidings.

As Section H.10.2 notes, NRC has addressed operating restrictions for tunnels by working with the Association of American Railroads to adjust rail operating practices. In addition, DOE has committed to supporting the NRC Package Performance Study to better understand severe accidents.

Academy Finding

The committee strongly endorses the use of full-scale testing to determine how packages will perform under both regulatory and credible extra-regulatory conditions. Package testing in the United States and many other countries is carried out using good engineering practices that combine state-of-the-art structural analyses and physical tests to demonstrate containment effectiveness. Full-scale testing is a very effective tool both for guiding and validating analytical engineering models of package performance and for demonstrating the compliance of package designs with performance requirements. However, deliberate full-scale testing of packages to destruction through the application of forces that substantially exceed credible accident conditions would be marginally informative and is not justified given the considerable costs for package acquisitions that such testing would require.

Academy Recommendation

Full-scale package testing should continue to be used as part of integrated analytical, computer simulation, scale-model, and testing programs to validate package performance. Deliberate full-scale testing of packages to destruction should not be required as part of this integrated analysis or for compliance demonstrations.

DOE would use NRC-certified casks for transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. Cask vendors would supply these NRC-certified casks to DOE under contractual requirements. To obtain the certificate, the vendors would conduct testing as NRC specifies.

H.10.3.2 *Route Selection for Research Reactor Spent Fuel Transport*

Academy Finding

> The Department of Energy's procedures for selecting routes within the United States for shipments of foreign research reactor spent fuel appear on the whole to be adequate and reasonable. These procedures are risk informed; they make use of standard risk assessment methodologies in identifying a suite of potential routes and then make final route selections by taking into account security, state and tribal preferences, and information from states and tribes on local transport conditions. The Department of Energy's procedures reflect the agency's position (which is consistent with Department of Transportation regulations) that the states are competent and responsible for selecting highway routes. For rail route selection, the Department of Energy's practice of negotiating routes with carriers in consultation with states is analogous to its interaction with states on highway routing.

Academy Recommendation

> The Department of Energy should continue to ensure the systematic, effective involvement of states and tribal governments in its decisions involving routing and scheduling of foreign and DOE research reactor spent fuel shipments.

For shipments to the repository, DOE would use its *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all) to guide interactions with state and tribal governments. During planning and actual transportation operations, DOE would involve these stakeholders in route identification, funding approaches for emergency response planning and training, understanding safeguards and security requirements, operational practices, and communications and information access.

DOE is working collaboratively with states through State Regional Group committees (whose members are state officials responsible for transportation policy, law enforcement, emergency response, and oversight of hazardous materials shipments) and with American Indian tribal governments to assist them to prepare for the shipments.

In addition to State Regional Group and tribal coordination, a national cooperative effort is underway as part of the Transportation External Coordination Working Group and its various Topic Groups, which involves a broad range of stakeholder organizations that routinely interact with DOE to provide input and recommendations on transportation planning and program information. States, tribes, and industry are working with DOE to guide and focus emergency training, coordination with local officials, and other transportation activities to prepare for shipments to the repository.

Academy Finding

> Highway routes for shipment of spent nuclear fuel are dictated by DOT regulations (49 CFR Part 397). The regulations specify that shipments normally must travel by the fastest route using highways designated by the states or the federal government. They do not require the carrier or shipper to evaluate risks of portions of routes that meet this criterion. These regulations are a satisfactory means of ensuring safe transportation, provided that the shipper actively and systematically consults with the states and tribes

along potential routes and that states follow the route designation procedures prescribed by the DOT.

Academy Recommendation

DOT should ensure that states that designate routes for shipment of spent nuclear fuel rigorously comply with its regulatory requirement that such designations be supported by sound risk assessments. DOT and DOE should ensure that all potentially affected states are aware of and prepared to fulfill their responsibilities regarding highway route designations.

DOE is working collaboratively with states through State Regional Group committees (whose members are state officials responsible for transportation policy, law enforcement, emergency response, and oversight of hazardous materials shipments) and with American Indian tribal governments to assist them to prepare for the shipments.

As part of the routing discussions, DOE has provided training to officials of these stakeholders on its routing model (TRAGIS; DIRS 181276-Johnson and Michelhaugh 2003, all) and the risk model (RADTRAN 5; DIRS 150898-Neuhauser and Kanipe 2000, all). If states or tribes choose to designate alternative highway routes, technical assistance is available from the experts at the national laboratories who manage these two models. In addition, State Regional Group staff support their states with routing assistance as part of the cooperative efforts DOE supports.

H.10.4 FUTURE CONCERNS FOR TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

H.10.4.1 *Mode for Transporting Spent Nuclear Fuel and High-Level Radioactive Waste to a Federal Repository*

Academy Finding

Transport of spent fuel and high-level waste by rail has clear safety, operational, and policy advantages over highway transport for large-quantity shipping programs. The committee strongly endorses DOE’s selection of the “mostly rail” option for the Yucca Mountain transportation program for the following reasons:

- It reduces the total number of shipments to the federal repository by roughly a factor of five, which reduces the potential for routine radiological exposures, conventional traffic accidents, and severe accidents.
- Rail shipments have a greater physical separation from other vehicular traffic and reduced interactions with people along transportation routes, which also contributes to safety.
- Operational logistics are simpler and more efficient.
- There is a clear public preference for this option.

The committee does not endorse the development of an extended truck transportation program to ship spent fuel cross-country or within Nevada should DOE fail to complete construction of the Nevada rail spur or procure the necessary rail equipment by the time the federal repository is opened.

Academy Recommendation

DOE should fully implement its mostly rail decision by completing construction of the Nevada rail spur, obtaining the needed rail packages and conveyances, and working with commercial spent fuel owners to ensure that facilities are available at plants to support this option. These steps should be completed before DOE commences the large-quantity shipment of spent fuel and high-level waste to a federal repository to avoid the need to procure infrastructure and construct facilities to support an extended truck transportation program. DOE should also examine the feasibility of further reducing its needs for cross-country truck shipments of spent fuel through the expanded use of intermodal transportation (i.e., combining heavy-haul truck, legal-weight truck, and barge) to allow the shipment of rail packages from plants that do not have direct rail access.

In this Repository SEIS, DOE analyzed the intermodal transfer of rail casks for generator sites that do not have direct rail access. The SEIS analysis identified nine such sites from which DOE would ship spent nuclear fuel or high-level radioactive waste using 2,650 truck shipments. In addition, DOE's transportation operational planning recognizes the value of barge and some heavy-haul truck shipments to maximize rail use to ship to the repository. DOE would address all modes of transportation in future transportation campaign plans.

H.10.4.2 *Route Selection for Transportation to a Federal Repository*

Academy Finding

DOE has not made public a specific plan for selecting rail and highway routes for transporting spent fuel and high-level waste to a federal repository. DOE also has not determined the role of its program management contractors in selecting routes or specific plans for collaborating with affected states, tribes, and other parties.

Academy Recommendation

DOE should identify and make public its suite of preferred highway and rail routes for transporting spent fuel and high-level waste to a federal repository as soon as practicable to support state, tribal, and local planning, especially for emergency responder preparedness. DOE should follow the practices of its foreign research reactor spent fuel transport program of involving states and tribes in these route selections to obtain access to their familiarity with accident rates, traffic and road conditions, and emergency responder preparedness within their jurisdictions. Involvement by states and tribes may improve the public acceptability of route selections and may reduce conflicts that can lead to program delays.

An initial step in the DOE planning process to ship spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain repository would be to identify a national suite of routes, both rail and highway, that DOE could use. Stakeholder groups are participating with DOE in this process by examining routing criteria the Department could use in the route identification process. State Regional Groups, American Indian tribes, transportation associations, industry, federal agencies, and local government organizations are some of the groups that work collaboratively with DOE in this process.

The work would be conducted through a topic group of the Transportation External Coordination Working Group. Broader public input would also be sought to collect comments on routing criteria and the process for developing a set of routes. Industry practices, DOE requirements, and analyses of regional routes that were evaluated by state organizations would be included in the process to identify a preliminary set of routes. Public involvement is central to contributing to a safe, efficient, and flexible transportation system.

H.10.4.3 *Use of Dedicated Trains for Transport to a Federal Repository*

Academy Finding

Studies carried out to date on transporting spent fuel by dedicated versus general trains have failed to show a clear radiological risk based advantage for either option. However, the committee finds that there are clear operational, safety, security, communications, planning, programmatic, and public preference advantages that favor dedicated trains. The committee strongly endorses DOE's decision to transport spent fuel and most high-level waste to a federal repository using dedicated trains.

Academy Recommendation

DOE should fully implement its dedicated train decision before commencing the large-quantity shipment of spent fuel and high-level waste to a federal repository to avoid the need for a stop gap shipping program using general trains.

DOE made a decision to use dedicated trains for its usual mode of shipment, which offers benefits that include efficient use of casks and rail cars, lower dwell time in rail yards and, in combination with other service features, direct service from origin to destination. DOE agrees with the Academy's recommendation.

H.10.4.4 *Acceptance Order for Commercial Spent Nuclear Fuel Transport to a Federal Repository*

Academy Finding

The order for accepting commercial spent fuel that is mandated by the Nuclear Waste Policy Act (NWPA) was not designed with the transportation program in mind. In fact, the acceptance order prescribed by the NWPA could require DOE to initiate its transportation program with long cross-country movements of younger (i.e., radiologically and thermally hotter) spent fuel from multiple commercial sites. There are clear transportation operations and safety advantages to be gained from shipping older (i.e., radiologically and thermally cooler) spent fuel first and for initiating the transportation program with relatively short, logistically simple movements to gain experience and build operator and public confidence.

Academy Recommendation

DOE should negotiate with commercial spent fuel owners to ship older fuel first to a federal repository or federal interim storage, except in cases (if any) where spent fuel storage risks at specific plants dictate the need for more immediate shipments of younger fuel. Should these negotiations prove to be ineffective, Congress should consider legislative remedies. Within the context of its current contracts with commercial spent fuel owners, DOE should initiate transport through a pilot program involving relatively short, logistically simple movements of older fuel from closed reactors to demonstrate the ability to carry out its responsibilities in a safe and operationally effective manner. DOE should use the lessons learned from this pilot activity to initiate its full-scale transportation program from operating reactors.

The terms of the "Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste" (10 CFR Part 961) require DOE to assign priority to those generator sites whose fuel was discharged earliest. This is usually called the "Oldest Fuel First" priority. DOE must pick up fuel from sites that were designated by those generators as those with the oldest fuel regardless of the location. At sites that were designated by the generators who own the oldest spent nuclear fuel, DOE must pick up fuel the generators have selected and that has cooled for at least 5 years.

Regardless of which fuel DOE would ship first, it would conduct the shipments safely in NRC-certified casks for that type of fuel.

H.10.4.5 *Emergency Response Planning and Training*

Academy Finding

Emergency responder preparedness is an essential element of safe and effective programs for transporting spent fuel and high-level waste. Emergency responder preparedness has so far received limited attention from DOE, states, and tribes for the planned transportation program to the federal repository. DOE has the opportunity to be innovative in carrying out its responsibilities for emergency responder preparedness. Emergency responders are among the most trusted members of their communities. Well-trained responders can become important emissaries for DOE's transportation program in local communities and can enhance community preparedness to respond to other kinds of emergencies.

Academy Recommendation

DOE should begin immediately to execute its emergency responder preparedness responsibilities defined in Section 180(c) of the Nuclear Waste Policy Act. In carrying out these responsibilities, DOE should proceed to (1) establish a cadre of professionals from the emergency responder community who have training and comprehension of emergency response to spent fuel and high-level waste transportation accidents and incidents; (2) work with the Department of Homeland Security to provide consolidated "all-hazards" training materials and programs for first responders that build on the existing national emergency response platform; (3) include trained emergency responders on the escort teams that accompany spent fuel and high-level waste shipments; and (4) use emergency responder preparedness programs as an outreach mechanism to communicate broadly about plans and programs for transporting spent fuel and high-level waste to a federal repository with communities along planned shipping routes.

The NWPA requires DOE to provide technical assistance and funds to states and American Indian tribes for training public safety officials of appropriate units of local governments through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste. Section 180(c) further provides that training cover procedures required for safe routing transportation of these materials, as well as procedures for dealing with emergency response situations. Section 180(c) indicates that funding for work under this subsection would come from the Nuclear Waste Fund. Once implemented, this program would provide the increment of funding and technical assistance necessary to train fire fighters, law enforcement officers, and other public safety officials in preparation for repository shipments through their jurisdictions.

To implement this requirement in the 1990s, DOE published four Federal Register notices soliciting public comments on its approach to implementing Section 180(c). Comments received in response to these notices were addressed in each subsequent Federal Register notice with the last notice issued in April 1998. In 2004, the changes in homeland security and DOE's transportation practices made it timely for DOE to renew efforts to develop Section 180(c) policy and implementation procedures. Changes in emergency preparedness and funding for responders since 1998 were reviewed and evaluated as well as emergency preparedness grant programs initiated after September 11, 2001. Programs developed by Department of Homeland Security and the Federal Emergency Management Agency were considered. Relevant DOE funding and emergency response training efforts such as the Waste Isolation Pilot Plant and Foreign Research Reactor transportation programs were also evaluated.

DOE's revisiting of Section 180(c) implementation began with the formation of the Transportation External Coordination Working Group 180(c) Topic Group in April 2005. DOE also worked with the state regional groups and the Tribal Issues Topic Group of the Transportation External Coordination Working Group to solicit stakeholder input on the policy. Topic Group members wrote issue papers on specific Section 180(c) topics such as allowable activities, funding allocation method, timing and eligibility, and definitions. From these materials, DOE developed a draft policy which it issued in a Federal Register Notice on July 23, requesting additional comments from stakeholders and the public. DOE plans to conduct a pilot to test the program, and then issue the final Section 180(c) Policy.

Under the proposed policy, two grants would be made available to eligible state and tribal governments. An initial assessment and planning grant would be available about four years prior to shipments commencing through a jurisdiction. Once the state or tribe completes the assessment and planning grant activities, they would be eligible for the training grant every year that shipments travel through their jurisdiction.

H.10.4.6 *Information Sharing and Openness*

Academy Finding

> There is a conflict between the open sharing of information on spent fuel and high-level waste shipments and the security of transportation programs. This conflict is impeding effective risk communication and may reduce public acceptance and confidence. Post–September 11, 2001, efforts by transportation planners, managers, and regulators to further restrict information about spent fuel shipments make it difficult for the public to assess the safety and security of transportation operations.

Academy Recommendation

> The Department of Energy, Department of Homeland Security, Department of Transportation, and Nuclear Regulatory Commission should promptly complete the job of developing, applying, and disclosing consistent, reasonable, and understandable criteria for protecting sensitive information about spent fuel and high-level waste transportation. They should also commit to the open sharing of information that does not

require such protection and should facilitate timely access to such information: for example, by posting it on readily accessible Web sites.

Interactions with state and tribal governments would be guided by the *Office of Civilian* Radioactive *Waste Management Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions* (DIRS 172433-DOE 2003, all). During planning and actual transportation operations, states, tribes, industry, and other key stakeholders would be involved in route identification, funding approaches for emergency response planning and training, understanding safeguards and security requirements, operational practices, and communications and information access.

In addition to key stakeholder organizations and groups, the public has access to transportation information through the DOE web page and through the Transportation External Coordination Working Group web page. These two mechanisms allow program information that should be shared reach a broad audience.

H.10.4.7 *Organizational Structure of the Federal Transportation Program*

Academy Finding

Successful execution of DOE's program to transport spent fuel and high-level waste to a federal repository will be difficult given the organizational structure in which it is embedded, despite the high quality of many current program staff. As currently structured, the program has limited flexibility over commercial spent fuel acceptance order (Section 5.2.4); it also has limited control over its budget and is subject to the annual federal appropriations process, both of which affect the program's ability to plan for, procure, and construct the needed transportation infrastructure. Moreover, the current program may have difficulty supporting what appears to be an expanding future mission to transport commercial spent nuclear fuel for interim storage or reprocessing. In the committee's judgment, changing the organizational structure of this program will improve its chances for success.

Academy Recommendation

The Secretary of Energy and the U.S. Congress should examine options for changing the organizational structure of the Department of Energy's program for transporting spent fuel and high-level waste to a federal repository. The following three alternative organizational structures, which are representative of progressively greater organizational change, should be specifically examined: (1) a quasi-independent DOE office reporting directly to upper-level DOE management; (2) a quasi-government corporation; or (3) a fully private organization operated by the commercial nuclear industry. The latter two options would require changes to the Nuclear Waste Policy Act. The primary objectives in modifying the structure should be to give the transportation program greater planning authority; greater budgetary flexibility to make the multiyear commitments necessary to plan for, procure, and construct the necessary transportation infrastructure; and greater flexibility to support an expanding future mission to transport spent fuel and high-level waste for interim storage or reprocessing. Whatever structure is selected, the organization should place a strong emphasis on operational safety and reliability and should be responsive to social concerns.

The NWPA defines the Federal Government's responsibilities for disposal of spent nuclear fuel and high-level radioactive waste. The NWPA created the Office of Civilian Radioactive Waste Management within DOE to carry out these responsibilities, which include the development of a transportation system. The Act requires the Office to maximize use of the private sector to implement its transportation responsibilities. That collaborative development effort is underway, and would continue until the law changed.

REFERENCES

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155970	DOE 2002	DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geological Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE/EIS- 0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; MOL.20020524.0315; MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319; MOL.20020524.0320.
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Appendix I

Federal Register Notices

APPENDIX I. FEDERAL REGISTER NOTICES

The following table lists Federal Register Notices used in this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D). Notices can be found on the U.S. Government Printing Office GPO Access website at http://origin.www.gpoaccess.gov/fr/.

Volume and Page	Publication Date	Title
60 FR 28680	June 1, 1995	Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs.
66 FR 14194	March 9, 2001	Notice of Realty Action: Public Law 106-113, as Amended, Non-Competitive Sale of Public Lands and the Conveyance of Public Lands for Recreation and Public Purposes.
67 FR 39737	June 10, 2002	Nye County Habitat Conservation Plan for Lands Conveyed at Lathrop Wells, NV.
67 FR 53359	August 15, 2002	Public Land Order No. 7534; Extension of Public Land Order No. 6802; Nevada.
67 FR 63167	October 10, 2002	In the Matter of All Power Reactor Licensees, Research and Test Reactor Licensees, and Special Nuclear Material Licensees Who Possess and Ship Spent Nuclear Fuel; Order Modifying License. (Effective Immediately)
67 FR 65539	October 25, 2002	Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV.
67 FR 65564	October 25, 2002	Environmental Impact Statements; Notice of Availability.
67 FR 79906	December 31, 2002	Record of Decision for the Final Environmental Impact Statement for the Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory.
68 FR 58815	October 10, 2003	Electronic Maintenance and Submission of Information; Final Rule. (Part 63—Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.)
68 FR 74951	December 29, 2003	Notice of Preferred Nevada Rail Corridor.
68 FR 74965	December 29, 2003	Notice of Proposed Withdrawal and Opportunity for Public Meeting; Nevada.
69 FR 2280	January 14, 2004	Changes to Adjudicatory Process 10 CFR Parts 1, 2, 50, 51, 52, 54, 60, 63, 70, 72, 73, 75, 76, and 110. (Part 63-- Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.)

Volume and Page	Publication Date	Title
69 FR 3698	January 26, 2004	Compatibility With IAEA Transportation Safety Standards (TS–R–1) and Other Transportation Safety Amendments.
69FR 18557	April 8, 2004	Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV.
69 FR 18565	April 8, 2004	Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV.
69 FR 22496	April 26, 2004	Comment Period Extension and Additional Public Scoping Meetings for an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV.
69 FR 52040	August 24, 2004	Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions.
69 FR 58841	October 1, 2004	Hazardous Materials Regulations; Compatibility With the Regulations of the International Atomic Energy Agency; Correction; Final Rule.
70 FR 35073	June 16, 2005	West Valley Demonstration Project Waste Management Activities.
70 FR 49014	August 22,2005	Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada; Proposed Rule.
70 FR 56647	September 28,2005	Notice of Intent To Prepare a Programmatic Environmental Impact Statement, Amend Relevant Agency Land Use Plans, Conduct Public Scoping Meetings, and Notice of Floodplain and Wetlands Involvement.
70 FR 75165	December 19, 2005	Office of Environmental Management; Record of Decision for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement.
70 FR 76854	December 28, 2005	Public Land Order No. 7653; Withdrawal of Public Lands for the Department of Energy To Protect the Caliente Rail Corridor; Nevada.
71 FR 10068	February 28, 2006	Notice of Issuance of Materials License Snm–2513 for the Private Fuel Storage Facility.
71 FR 60484	October 13, 2006	Amended Notice of Intent To Expand the Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV.

Volume and Page	Publication Date	Title
71 FR 60490	October 13, 2006	Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV.
71 FR 61731	October 19, 2006	Notice of Intent To Prepare a Supplement to the Stockpile Stewardship and Management Programmatic Environmental Impact Statement—Complex 2030.
71 FR 65785	November 9, 2007	Extension of Public Comment Period and Additional Public Meeting for the Supplemental Yucca Mountain Rail Corridor and Rail Alignment Environmental Impact Statement.
71 FR 65786	November 9, 2006	Extension of Public Comment Period and Additional Public Meeting for the Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV.
72 FR 331	January 4, 2007	Notice of Intent To Prepare a Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership.
72 FR 1235	January 10, 2007	Notice of Proposed Withdrawal and Opportunity for Public Meeting; Nevada.
72 FR 14543	March 28, 2007	Notice of Intent To Prepare a Supplemental Environmental Impact Statement for Surplus Plutonium Disposition at the Savannah River Site.
72 FR 40135	July 23, 2007	Notice of Intent To Prepare an Environmental Impact Statement for the Disposal of Greater-Than-Class-C Low-Level Radioactive Waste.

Appendix J

Distribution List

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J. DISTRIBUTION LIST

J.1 United States Congress

The U.S. Department of Energy is providing copies of this *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1D) to federal, state, and local elected and appointed officials and agencies of government; American Indian groups; national, state, and local environmental and public interest groups; and other organizations and individuals listed below. Copies will be provided to other interested parties upon request.

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J.3 State of Nevada

J.3.1 STATEWIDE OFFICES AND LEGISLATURE

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The Honorable John Lee
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The Honorable William J. Raggio
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The Honorable Alice Constandina (Dina) Titus
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Nevada State Assembly

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The Honorable Dean A. Rhoads
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The Honorable Garn Mabey
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The Honorable Nancy Boland, Chair
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Mr. Robert List
Principal Consultant
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Esmeralda County Repository Oversight
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Inyo County

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Nuclear Waste Liaison

The Honorable Wade Poulsen, Vice Chair
Board of Lincoln County Commissioners

Mr. Mike Baughman
Intertech Services Corporation

The Honorable Edward Fowler, Chair
Mineral County Board of Commissioners

Ms. Linda Mathias
AUG Representative
Mineral County

The Honorable Joni Eastley, Vice Chair
Nye County Board of Commissioners

The Honorable Clinton "Brent" Eldridge
Chair
White Pine County Commission

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The Honorable Susan Holecheck
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City of Mesquite

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The Honorable Geno Martini
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The Honorable Jim Bilyeu, Chair
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The Honorable Susan Cash
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The Honorable Ronda Hammond-Hornbeck
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Lincoln County Board of Commissioners

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The Honorable Roger Tobler
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The Honorable Kevin J. Phillips
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City of Henderson

Mr. Marc Jordan, Planning Manager
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Development Dept.

The Honorable Robert A. Cashell, Sr.
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City of Reno

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Pershing County Board of Commissioners

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Lyon County

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The Honorable John H. Milton III
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The Honorable Ken Tedford, Jr.
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City of Fallon

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J.4 Other States and Territories

The Honorable Anibal Acevedo-Vila
Governor of Puerto Rico

The Honorable John E. Baldacci
Governor of Maine

The Honorable Mike Beebe
Governor of Arkansas

The Honorable Kathleen Babineaux Blanco
Governor of Louisiana

The Honorable Phil Bredesen
Governor of Tennessee

The Honorable Jon S. Corzine
Governor of New Jersey

The Honorable Mitch Daniels
Governor of Indiana

The Honorable Jim Doyle
Governor of Wisconsin

The Honorable Ernie Fletcher
Governor of Kentucky

The Honorable Jennifer M. Granholm
Governor of Michigan

The Honorable Dave Heineman
Governor of Nebraska

The Honorable John Hoeven
Governor of North Dakota

The Honorable Timothy "Tim" M. Kaine
Governor of Virginia

The Honorable Linda Lingle
Governor of Hawaii

The Honorable Joe Manchin, III
Governor of West Virginia
The Honorable Ruth Ann Minner
Governor of Delaware

The Honorable Martin O'Malley
Governor of Maryland

The Honorable Sarah H. Palin
Governor of Alaska

The Honorable Timothy Pawlenty
Governor of Minnesota

The Honorable Rick Perry
Governor of Texas

The Honorable Edward G. Rendell
Governor of Pennsylvania

The Honorable Robert "Bob" R. Riley
Governor of Alabama

The Honorable Bill Ritter, Jr.
Governor of Colorado

The Honorable Arnold Schwarzenegger
Governor of California

The Honorable Kathleen Sebelius
Governor of Kansas

The Honorable Ted Strickland
Governor of Ohio

The Honorable Eliot Spitzer
Governor of New York

The Honorable Haley Barbour
Governor of Mississippi

The Honorable Rod R. Blagojevich
Governor of Illinois

The Honorable Matt Blunt
Governor of Missouri

The Honorable Donald L. Carcieri
Governor of Rhode Island

The Honorable Felix Camacho
Governor of Guam

The Honorable Charlie Crist
Governor of Florida

The Honorable Chet Culver
Governor of Iowa

The Honorable James H. Douglas
Governor of Vermont

The Honorable Michael F. Easley
Governor of North Carolina

The Honorable David D. Freudenthal
Governor of Wyoming

The Honorable Christine O. Gregoire
Governor of Washington

The Honorable Charles Bradford "Brad" Henry
Governor of Oklahoma

The Honorable Jon M. Huntsman, Jr.
Governor of Utah

The Honorable Ted Kulongoski
Governor of Oregon

The Honorable Frank Murkowski
Governor of Alaska

The Honorable John H. Lynch
Governor of New Hampshire

The Honorable Janet Napolitano
Governor of Arizona

The Honorable C. L. Butch Otter
Governor of Idaho

The Honorable Deval Patrick
Governor of Massachsetts

The Honorable Sonny Perdue
Governor of Georgia

The Honorable M. Jodi Rell
Governor of Connecticut

The Honorable William "Bill" Richardson
Governor of New Mexico

The Honorable Michael M. Rounds
Governor of South Dakota

The Honorable Mark Sanford
Governor of South Carolina

The Honorable Brian Schweitzer
Governor of Montana

The Honorable Togiola Tulafono
Governor of American Samoa

J.5 Native American Tribes and Organizations

Mr. Kenny Anderson
Tribal Representative
Las Vegas Paiute Tribe

The Honorable John Azbil, Sr.
President
Round Valley Indian Tribal Council

The Honorable Eleanor Baxter
Chairwoman
Omaha Tribe of Nebraska

The Honorable Kristi Begay
Tribal Chair
Wells Indian Colony Band Council

The Honorable Leonard Beowman
Chairman
Bear River Band of the Rohnerville Rancheria, California

The Honorable John Blackhawk
Chairman
Winnebago Tribe of Nebraska

The Honorable Diana Buckner
Chairwoman
Ely Shoshone Tribe

Ms. Ila Bullets
Tribal Representative
Kaibab Band of Southern Paiutes

The Honorable Delia Carlyle
Chairwoman
Ak Chin Indian Community Council

Mr. Lee Chavez
Tribal Representative
Bishop Paiute Indian Tribe

Mr. Vince Conway
Tribal Chairman
Yerington Paiute Tribe

Ms. Betty L. Cornelius
Tribal Representative
Colorado River Indian Tribes

The Honorable Carl Dahlberg
Chairman
Fort Independence Indian Tribe

Ms. Brenda Drye
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Kaibab Band of Southern Paiutes

The Honorable Daniel Eddy, Jr.
Chairman
Colorado River Indian Tribes

The Honorable Blaine Edmo
Chairman, Business Council
Shoshone-Bannock Tribes of the Fort Hall Reservation of Idaho

Ms. Pauline Esteves
Tribal Representative
Timbisha Shoshone Tribe

The Honorable Darrell Flyingman
Chairman
Cheyenne-Arapaho Tribes of Oklahoma

The Honorable Harold Frank
Chairman
Forest County Potawatomi Community of Wisconsin

Ms. Grace Goad
Tribal Representative
Timbisha Shoshone Tribe

The Honorable Lori Harrison
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Las Vegas Indian Center

Mr. John A. James
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Cabazon Band of Mission Indians

Mr. Mel Joseph
Tribal Representative
Lone Pine Paiute-Shoshone Tribe

Mr. Darryl King
Tribal Representative
Chemehuevi Tribe

Ms. Jacqueline Johnson
Executive Director
National Congress of American Indians

The Honorable Joe Kennedy
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Timbisha Shoshone Tribe

Mr. Bill R. Larson
Shoshone Nation/Tribe

Mr. Bill Larson
Western Shoshone Defense Project

The Honorable George R. Lewis
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Ho-Chunk Nation of Wisconsin

The Honorable Maurice Lyons
Chairman
Morongo Band of Cahuilla Mission Indians of the Morongo Reservation, California

The Honorable Nora McDowell
Chairwoman
Fort Mojave Indian Tribe of Arizona, California & Nevada

The Honorable Dean Mike
Chairman
Twenty-Nine Palms Band of Mission Indians of California

The Honorable Richard M. Milanovich
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Mr. Wilfred Nabahe
Tribal Representative
Lone Pine Paiute-Shoshone Tribe

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The Honorable William R. Rhodes
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Gila River Indian Community of the Gila River Indian Reservation, Arizona

The Honorable Ruby Sam
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The Honorable Ona Segundo
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The Honorable Joe Shirley, Jr.
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Navajo Nation, Arizona, New Mexico & Utah

The Honorable Ivan L. Sidney
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Hopi Tribe of Arizona

Mr. Philbert Swain
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Ms. Theresa A. Stone-Yanez
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The Honorable Glenn Wasson
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The Honorable Lee Watterson
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The Honorable Leona L. Williams
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Pinoleville Rancheria of Pomo Indians of California

The Honorable Marjianne Yonge
Chairwoman
Lone Pine Paiute-Shoshone Tribe

The Honorable Richard Arnold
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Pahrump Paiute Tribe

Ms. Sandra Barela
Tribal Representative
Ely Shoshone Tribe

The Honorable John A. Barrett
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Citizens Band of Potawatomi (OK)

The Honorable Homer Bear, Jr.
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Sac & Fox Tribal of the Mississippi in Iowa

The Honorable Audrey Bennett
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The Honorable Dennis Bill
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The Honorable Claudia Brundin
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Blue Lake Racheria Indian Tribe

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The Honorable Fred Cantu
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Moapa Band of Paiute Indians

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Ms. Barbara Durham
Tribal Representative
Timbisha Shoshone Tribe

Mr. Atef Elzeftawy
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Mr. Ron Escobar
Tribal Representative
Chemehuevi Tribe

The Honorable John Feliz, Jr.
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Coyote Valley Band of Pomo Indians of California

Mr. Maurice Frank-Churchill
Tribal Representative
Duckwater Shoshone Tribe

The Honorable Elizabeth Hansen
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Redwood Valley Rancheria of Pomo Indians of California

Mr. Bill Helmer
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Big Pine Pauite Tribe of the Owens Valley

The Honorable Mike Jackson, Sr.
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Quechan Tribe of the Fort Yuma Indian Reservation, California & Arizona

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Pahrump Paiute Tribe

Mr. Gerald Kane
Tribal Representative
Bishop Paiute Indian Tribe

The Honorable Roland E. Johnson
Governor
Pueblo of Laguna, New Mexico

The Honorable Jason Johnson
Governor
Pueblo of Acoma, New Mexico

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Reno-Sparks Indian Tribe

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The Honorable Virgil Moose
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Big Pine Paiute Tribe of the Owens Valley

The Honorable Larry Nuckolls
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Absentee Shawnee Tribe of Indians of Oklahoma

The Honorable Kay Rhoads
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Sac & Fox Nation, Oklahoma

The Honorable Tony Salazar
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The Honorable Joseph C. Saulque
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The Honorable George Scott
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The Honorable Arturo Senclair
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The Honorable Barry E. Snyder, Sr.
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Genia Williams
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Emergency Management & Radioactive Programs

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Citizens Against Nuclear Trash

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The Nature Conservancy

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Economists for Peace & Security at the Levy Institute

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President
Committee to Bridge the Gap

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Mr. Michael McCally
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Mr. Gerald Pollet
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Heart of America Northwest

Mr. Richard J. Sawicki
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Ms. Kassie Siegel
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Center for Biological Diversity

Jennifer Olaranna Viereck
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Mr. Jim Riccio
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Ms. Meg Power
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The Nature Conservancy

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Tri-Valley CAREs

Ms. Tonya Kleuskens
President
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Mr. Ronald Lamb
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Mr. Lloyd Leonard
League of Women Voters

Mr. Kevin Martin
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Dr. Mildred McClain
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Harambee House, Inc.
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Citizens Advisory Council

Mr. Richard Moore
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Southwest Network for Environmental & Economic Justice

Robert K. Musil, Ph.D.
Executive Director and CEO
Physicians for Social Responsibility

Mr. Ehrich Pica
Friends of the Earth

Ms. Laura Raicovich
Dia Art Foundation

Ms. Susan Shaer
Executive Director
Women's Action for New Directions

Ms. Gail Small
Executive Director
Native Action

Mr. Derek Stack
Executive Director
Great Lakes United

Ms. Peggy Maze Johnson, Executive Director
Citizens Alert

J.7 Other Groups and Individuals

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Tempiute Grazing Association

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Mr. William Ramsey
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Troutman Sanders

Dr. Budhi Sagar
Technical Director
Southwest Research Institute
Center for Nuclear Waste Regulatory Analyses

Dr. Stephen Wells
President
Desert Research Institute

Ms. Barbara Bauman Tyran
Director, Washington Relations
Electric Power Research Institute

Ms. Anna Aurilio
Director, Washington, DC Office
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Thomas B. Cochran, Ph.D.
Director, Nuclear Programs
Natural Resources Defense Council, Inc.
Washington Office

Mr. David Hawkins
Director, Climate Center
Natural Resources Defense Council
Washington Office

Mr. Ace Robison
Consultant

Dr. David Shafer
Executive Director
CERM, Desert Research Institute
Center for Environmental Remediation & Monitoring

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American Public Power Assoc.

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International Association of Emergency Managers
c/o General Physics Corporation

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FRA/State Rail Safety Participation Program
c/o Transportation Division
Ohio Public Utilities Commission

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National Governors' Association

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Mr. Robert Thompson
Energy Communities Alliance

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University of Nevada, Las Vegas
Harry Reid Center

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Assistant Director
Natural Land Institute

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Consultant
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Ms. Mary Olson
Radioactive Waste Project & NIX MOX Campaign
Nuclear Information & Resource Service

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University of Nevada, Las Vegas
Harry Reid Center for Environmental Studies

ENV1 - Environmental Not VIP Jackie Cabasso
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Natural Resources Defense Council
Public Education

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International Relations Center

Mr. Kevin Kamps
Nuclear Information & Resource Service

Mr. Paul Leventhal
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Nuclear Control Institute

Arjun Makhijani, Ph.D.
President
Institute for Energy & Environmental Research (IEER)

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Nye Regional Medical Center

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Nevada Commission on Nuclear Projects

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National Association of Attorneys General (NAAG)

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Western Regional Air Partnership

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American Nuclear Insurers

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Director
National Science Foundation

Mr. Anthony DeSouza
Director, Board on Earth Studies & Natural Sciences
National Academy of Sciences

J.8 Reading Rooms and Libraries

Esmeralda County Yucca Mountain Oversight Office
Goldfield, NV

Nye County Department of Natural Resources and Federal Facilities
Pahrump, NV
U.S. Department of Energy Headquarters Office Public Reading Room
Washington, D.C.

Ms. Susan Beard
Librarian
Northern Arizona University
Cline Library

Ms. Michelle Born
Librarian
Clark County Library
Main Branch
Reference Department

Mr. Bert Chapman
Purdue University
Hesse Library - Documents Department

Ms. Pauline Conner
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Savannah River Operations
University of South Carolina-Aiken, Gregg-Graniteville Library
Public Reading Room

Ms. Kathy Edwards
Nevada State Library & Archives

Ms. Amy Sue Goodin
Associate Director of Research
University of New Mexico
Institute for Public Policy

Ms. Sandra Groleau
Bates College Library

Ms. Paige Harper
University of Florida
Documents Department

Ms. Deanna Harvey
Strategic Petroleum Reserve Project Management Office
SPRPMO/Reading Room

Mr. John Horst
National Renewable Energy Lab
Public Reading Room

Librarian, Government Documents
University of New Hampshire
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Librarian
San Jose State University
Martin Luther King, Jr. Library
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Librarian
University of Colorado, Boulder
Library - Government Publications

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University Library, California State University
Government Documents

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Susanville District Library

Librarian
Sparks Branch Library

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Fishlake Branch Library

Librarian
Carson City Library
Reference Department

Librarian
Laughlin Branch Library

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Needles Library

Librarian
Round Mountain Public Library

Librarian
University of Wisconsin, Madison
Wendt Library - Technical Reports Center

Librarian
University of Texas, San Antonio
Library - Government Documents Department

Mrs. Pat Loper
Great Basin College Library

Mr. Joseph Milazzo
Southern Methodist University
Fondren Library East
Government Information

Ms. Janice Parthree
U.S. Department of Energy
Richland Operations Center
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Public Affairs Director
Consumer Energy
Big Rock Point

Mr. William H. Schalk
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American Electric Power Company
Cook Visitor Information Center

Ms. Susie Skarl
Head, Government Publications
University of Nevada, Las Vegas
Lied Library

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Center for Health, Environment and Justice
CHEJ Library

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AFL-CIO

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W. A. Armstrong
Preservation Capital Corp

Mr. Gerald W. Baughman
Nevada Eagle Resources, LLC
Lincoln County Nuclear Waste Project Office
Caliente, NV

Pahrump Yucca Mountain Information Center
Pahrump, NV

The University of Nevada Libraries
Business and Government Information Center
Reno, NV

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University of New Mexico
Zimmerman Library

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Langson Library

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University of California, Santa Barbara
Davidson Library - Government Information Center

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Clearinghouse Coordinator, Nevada State Clearinghouse
Department of Administration
State of Nevada
Public Reading Room

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J.W. Martin Library Depository

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Mr. Walter Jones
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Marriott Library, Special Collections

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Rivera Library - Government Publications Department

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