APPENDIX I

NOISE AND VIBRATION IMPACT ASSESSMENT METHODOLOGY

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APPENDIX I

NOISE AND VIBRATION IMPACT ASSESSMENT METHODOLOGY

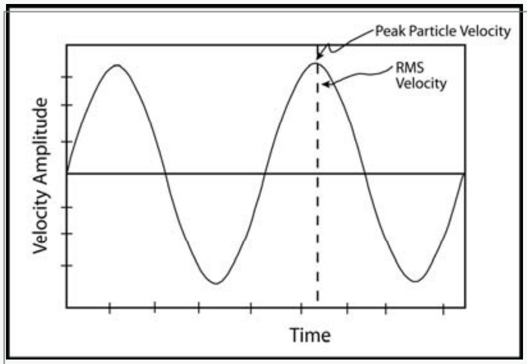
This appendix provides detailed information on the methodology DOE used to develop the assessment of potential impacts from noise and vibration described in Sections 4.2.8 and 4.3.8 of the Rail Alignment EIS (DOE/EIS-0639D).

Section **I.4** defines terms shown in ***bold italics***.

I.1 Noise and Vibration Terminology

Noise is considered a source of pollution because it can be a human health hazard. Potential health hazards range from hearing impairment at very high noise levels to annoyance at moderate to high noise levels. Noise is defined as sound waves that are unwanted and perceived as a nuisance by humans. Sound waves are characterized by frequency and measured in ***hertz***; sound pressure level is expressed as ***decibels*** (dB).

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Many federal agencies use ***day-night average noise levels*** (DNL) as guidelines for land-use compatibility and to assess the impact of noise on people. Noise levels for perceptible frequencies are weighted (***A-weighted decibels*** [dBA]) to simulate the frequency response of the human ear.



Peak particle and root-mean-square vibration velocity

Wayside noise refers collectively to train noise generated by steel wheels rolling on steel rail and diesel engine noise. Horn noise refers to the sound of locomotive warning horns, which are sounded at railroad crossings. Horn noise typically dominates over wayside noise at locations near grade crossings. There are three ground-vibration impacts of general concern: annoyance to humans, damage to buildings, and interference with vibration-sensitive activities. There are two measurements for evaluating ground vibration**:** ***peak particle velocity*** and ***root-mean-square velocity***. Peak particle velocity is the maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per time (such as millimeters or inches per second). This measurement has been used historically to evaluate shock-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage. The root-mean-square velocity is an average or smoothed vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001 (10^{-6}) inch per second and is not to be confused with noise decibels (DIRS 155970-DOE 2002, p. 3-101). It is more suitable for addressing human annoyance and characterizing background vibration conditions because it better represents the response time of humans to ground vibration signals. A typical background level of ground vibration is

52 VdB, and the human threshold for the perception of ground vibration is 65 VdB (DIRS 148155-Hanson, Saurenman, and Towers 1998, p. 46.17).

Vibration criteria for structural damage in fragile or extremely fragile buildings have separate structural criteria based on peak particle velocity and an approximation of VdB that have been segregated into impulse and rail impacts. Table I-1 lists these criteria.

Table I-1. Benchmark ground-vibration criteria for buildings and human annoyance.[a]

		Infrequent events (fewer than 70 per day)		
Category	Frequent events (more than 70 per day) VdB[b]	Peak particle velocity (inches per second)[c]	VdB	Impact of concern
Annoyance or interference				
Highly sensitive building[d]	65	NA[e]	65	Sensitive equipment
Residential[f]	72	NA	80	Human disturbance
Institutional[g]	75	NA	83	Human disturbance
Structural damage				
Fragile buildings	NA	0.20	Approximately 100 (impulse) 92 (rail)	Structural damage
Extremely fragile buildings	NA	0.12	Approximately 95 (impulse) 88 (rail)	Structural damage

a. Source: DIRS 177297- Hanson, Towers, and Meister 2006, pp. 8-3 and 12-13.
b. Root-mean-square velocity expressed in decibels (VdB) referenced to 10^{-6} inch per second.
c. To convert to millimeters per second, multiply by 25.4.
d. Buildings with vibration-sensitive equipment (for example, at research institutions and medical facilities).
e. NA = not applicable.
f. Homes or buildings where people sleep.
g. Schools, churches, and office buildings.

I.2 Noise Analysis Methodology

DOE used the following methods to determine if constructing and operating the proposed rail line would result in an increase of the DNL of 3 dBA and if the DNL would equal or exceed 65 dBA:

- Noise Models – DOE used a wayside noise model, based on past Surface Transportation Board (STB) noise studies including the *Conrail Acquisition Environmental Impact Statement* (DIRS 174622-STB 1997, all) and the *Draft Environmental Assessment for the Canadian National/Illinois Central Acquisition Environmental Assessment* (DIRS 174623-Kaiser 1998, all). Section I.2.1 lists the equations for this model. The horn noise model is based on data from the *Draft Environmental Impact Statement, Proposed Rule for the Use of Locomotive Horns at Highway-Rail Grade Crossings* (DIRS 174551-DOT 1999, all; the 1999 Federal Railroad Administration DEIS). The overall noise model results are sensitive to horn noise, locomotive and railcar noise, train length, and train speed. DOE used wayside reference levels, the horn noise model, and equations shown in this appendix to generate noise contours. Finally, DOE used Cadna (DIRS 178129-DataKustik [n.d.], all), an environmental noise computer program, to calculate building shielding effects, where appropriate.

DOE selected the individual components of the overall noise model because of the size of the noise measurement database, statistical reliability, and other factors.

- Measure Ambient Noise – To establish a baseline for determining if there would be a 3 dBA or greater increase in noise, DOE measured ambient noise in the study area at seven representative locations – Caliente, Garden Valley, Goldfield, Silver Springs, Schurz, Mina, and Silver Peak. Substantial train activity already exists in Caliente; therefore, DOE used a combination of modeling and measurements to determine the difference between existing and future noise levels in that area. DOE measured ***ambient noise*** levels using Norsonics 118 octave band analyzers. For low ambient sound environments, DOE used special low-noise 1-inch-diameter precision microphones. DOE measured vibration levels with a Rion SA-77 narrow band analyzer and high sensitivity seismic accelerometers.
- Estimate or Measure Existing and Future Noise Exposure – DOE estimated noise exposure in terms of the DNL using information on distances and noise propagation paths to sensitive receptors and future operation plans.
- Count Noise-Sensitive Receptors – DOE estimated the number of noise-sensitive receptors within the 65 DNL noise contours for the Proposed Action and Shared-Use Option, or where the DNL would increase by at least 3 dBA. DOE used digital aerial photographs and Geographic Information System software to estimate the number of receptors, including residences, schools, and places of worship, within the 65 DNL noise contour for future train volumes. The final result of this analysis was an estimate of the total number of receptors likely to be exposed to a DNL of 65 dBA or greater and the number of receptors where the DNL would increase by at least 3 dBA under the Proposed Action or the Shared-Use Option.

I.2.1 WAYSIDE NOISE MODEL METHODOLOGY

Wayside noise refers collectively to noise the railcars and locomotives would generate. DOE used noise measurements of past STB noise studies (including DIRS 174622-STB 1997, all; DIRS 174623-Kaiser 1998, all) to establish the basis for the wayside noise level projections. Noise from railcars is caused by the steel wheels rolling on the steel rails. This sound is referred to as wheel/rail noise. Wheel/rail noise varies as a function of speed and can increase by as much as 15 dBA if wheels or rails are in poor condition. One of the most common problems that creates additional noise from wheels is the formation of flat surfaces on wheels caused by wheels sliding during hard braking.

The main components of locomotive noise are the exhaust of the diesel engines, cooling fans, general engine noise, and the wheel/rail interaction. Noise associated with the engine exhaust and cooling fans usually dominates; the noise level depends on the throttle setting (most locomotives have eight throttle settings) and not on locomotive speed.

Tests have shown that locomotive noise levels change by about 2 dBA for each step change in throttle setting, meaning that noise levels increase by about 16 dBA as the locomotive throttle is moved from notch one to notch eight (DIRS 174623-Kaiser 1998, all). Because locomotive engineers constantly adjust throttle settings as necessary, only rough estimates of throttle settings are usually available for noise projections. Numerous field measurements of freight train operations indicate that locomotive noise can be projected with reasonable accuracy by assuming a base condition of throttle position six and adjusting noise levels when better information about typical throttle position is known.

Given the maximum train passby sound level of freight cars and a locomotive under a specific set of reference conditions, the noise models allow estimating the maximum train passby sound level, the sound exposure level, the DNL, and other noise metrics for varying distances from the track, varying train speeds, and varying schedules. The standard approach to projecting railcar noise is to model cars as moving, incoherent (in other words, random), dipole line sources, wherein the cars are sources of sound moving in a straight line, which is equal in both directions from the track center line. The basic equations used for the wayside noise model are:

$$SEL_{cars} = L_{eqref} + 10\log(T_{passby}) + 30\log(S/S_{ref})$$

For locomotives, which can be modeled as moving monopole point sources, the corresponding equation is:

$$SEL_{locos} = SEL_{ref} + 10\log(N_{locos}) - 10\log(S/S_{ref})$$

The total train sound exposure level is computed by logarithmically adding SEL_{locos} and SEL_{cars}:

$$DNL_{100'} = SEL + 10\log(N_d + 10*N_n) - 49.4$$

$$DNL = DNL_{100'} + 15\log(100/D)$$

The parameters that apply to the equations above are:

SEL_{cars} = Sound Exposure Level of rail cars

L_{eqref} = Reference Level Equivalent of rail car (passby L_{eq})

T_{passby} = Train passby time, in seconds

S = Train speed, in miles per hour

S_{ref} = Reference train speed

SEL_{locos} = Sound Exposure Level of locomotive

SEL_{ref} = Reference Sound Exposure Level of locomotive

N_{locos} = Number of locomotives

N_d = Number of trains during daytime

N_n = Number of trains during nighttime

D = Distance from tracks, in feet

Table I-2 shows the reference noise levels used in this study.

Table I-2. Reference noise levels.[a]

Description	Average level (dBA)
Horn SEL 1st 0.125 mile[b,c]	107
Horn SEL 2nd 0.125 mile[c]	110
Locomotive SEL (40 miles per hour at 100 feet)[d]	95
Railcar L_{eq} (40 miles per hour at 100 feet)[e]	82

a. dBA = A-weighted decibels; L_{eq} = equivalent sound level; SEL = sound exposure level.
b. To convert miles to kilometers, multiply by 1.6093.
c. Source: DIRS 174551-DOT 1999, all.
d. Source: DIRS 174622-STB 1997, all.
e. Source: DIRS 174623-Kaiser 1998, all.

I.2.2 HORN NOISE MODEL METHODOLOGY

The key components in projecting noise exposure from horn noise are the horn sound level, the duration of the horn noise, the distance of the receptor from the tracks, and the number of trains running during daytime and nighttime hours.

The Federal Railroad Administration requires train engineers to sound horns when approaching public grade crossings unless a Quiet Zone has been established. Horn sounding is generally not required at private crossings. Federal Railroad Administration regulations in 49 CFR 229.129 require all lead locomotives to have an audible warning device that produces a minimum sound level of 96 dBA at a distance of 30 meters (100 feet) in front of the locomotive.

Most freight train audible warning devices are air horns. The maximum sound level of the air horns can usually be adjusted to some degree by adjusting the air pressure. Maximum sound levels are typically 105 to 110 dBA at 30 meters (100 feet) in front of the trains, well above the 96 dBA required by the Federal Railroad Administration.

The Federal Railroad Administration finalized its rule on horn noise on April 27, 2005 (*Use of Locomotive Horns at Highway-Rail Grade Crossings; Final Rule (*70 *Federal Register* 21843). This rule essentially provides communities with means to establish Quiet Zones in which horns are not sounded if sufficient safety measures are installed at grade crossings. The rule will also likely have an effect on horn noise levels nationally because of a number of changes in how horns will be sounded. For example, the rule limits the maximum level to 110 dBA. Previously, there were no maximum horn noise level limits. Additionally, the noise measurement technique used to establish horn noise levels will change and limits on how long horns can be sounded will be implemented. All of these changes will likely result in somewhat lower horn noise levels nationally.

Because of the high noise levels created by train horns, noise exposure is dominated by horn noise near any grade crossing where sounding horns is required. Additional noise sources associated with grade crossings are the grade-crossing bells that start sounding just before the gates are lowered and idling traffic that must wait at the crossing. Such noises are usually insignificant compared to the horn noise. Freight train horn noise levels can vary for a variety of reasons, including the manner in which an engineer sounds the horn. Consequently, it is important to base horn noise reference levels on a large sample size. A substantial amount of horn noise data is available from the 1999 Federal Railroad Administration DEIS (DIRS 174551-DOT 1999, all).

The Federal Railroad Administration data indicate that horn noise levels increase from the point at which the horn is sounded 0.40 kilometer (0.25 mile) from the grade crossing to when it stops sounding at the grade crossing. In the first 0.2-kilometer (0.125-mile) segment, the energy average sound exposure level measured at a distance of 30 meters (100 feet) from the tracks was found to be 107 dBA, and in the second 0.2-kilometer segment, 110 dBA. The 1999 Federal Railroad Administration DEIS (DIRS 174551-DOT 1999, all) simplified the horn noise contour shape as a five-sided polygon, when it is actually a teardrop shape. The *Final Environmental Impact Statement, Construction and Operation of a Rail Line from the Bayport Loop in Harris County, Texas* (DIRS 173225-STB 2003, all) discusses this subject in detail. DOE used the more accurate teardrop horn noise contour shape for this analysis. The attenuation or drop-off rate of horn noise is assumed to be 4.5 dBA per doubling of distance away from the tracks (DIRS 174551-DOT 1999, all).

To properly calculate building shielding effects, both wayside and horn noise were characterized by representative frequency spectra. Low-frequency sound can diffract or bend more easily than high-frequency sound over or around buildings or terrain; therefore, it is important to model horn and wayside noise separately according to frequency content. Figures I-1 and I-2 show these representative horn and

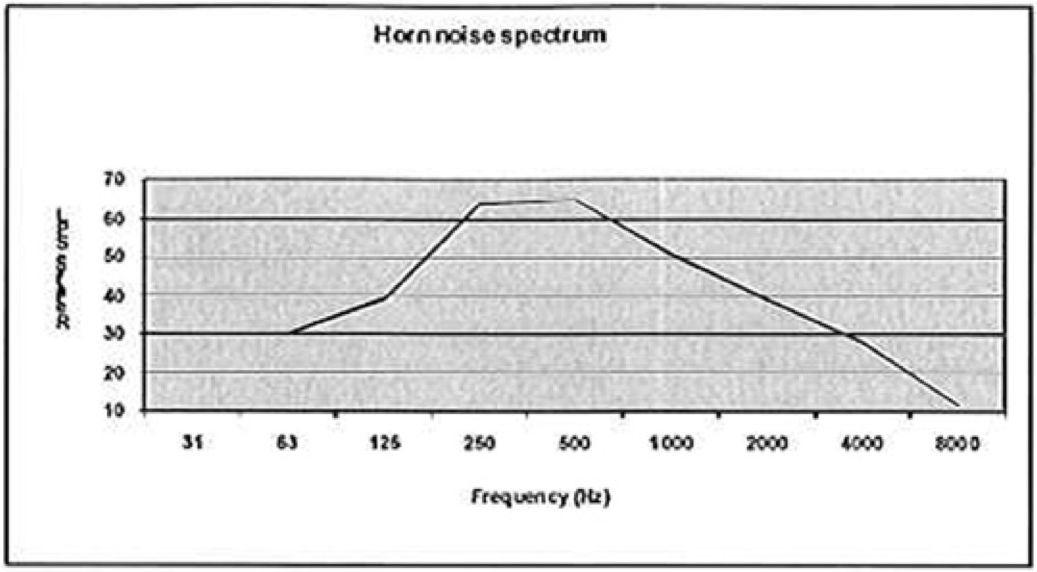


Figure I-1. Horn noise spectrum. (Source: DIRS 173225-STB 2003, p. 4-34. Hz = hertz; SPL = sound pressure level.)

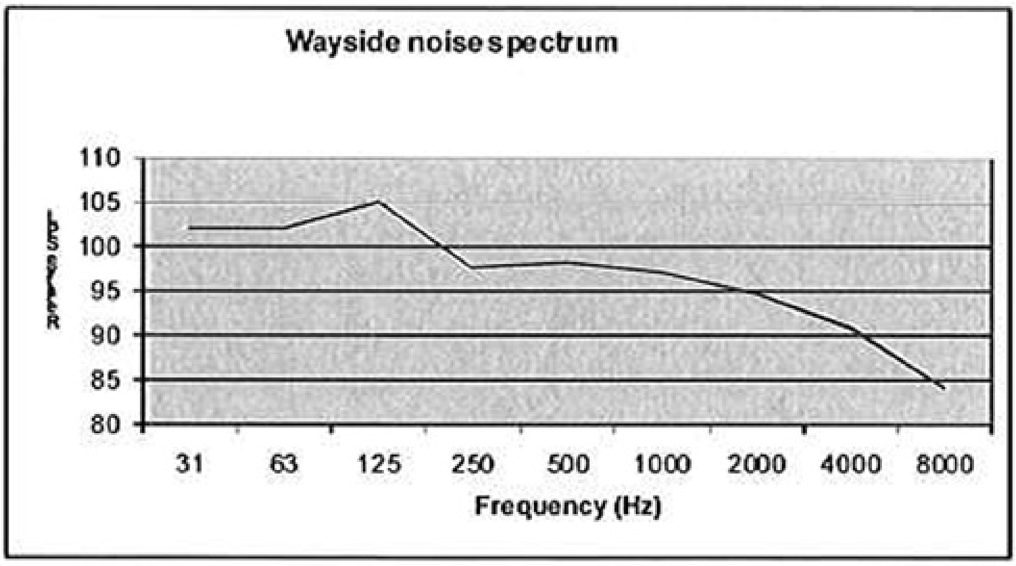


Figure I-2. Wayside noise spectrum. (Source: DIRS 173225-STB 2003, p. 4-34. Hz = hertz; SPL = sound pressure level.)

wayside noise spectra. The relative spectrum shapes and absolute noise levels shown in Table I-2 were used in the modeling.

In general, the tear-drop shapes, shown in the figures in Section 4.2.8 and 4.3.8 of the Rail Alignment EIS, are noise contours at grade crossings where horns might be sounded; noise contours shown in other areas are due to wayside noise. DOE used the noise contours in these figures, aerial photographs, and Geographic Information System software to identify and count any receptors that would be exposed to 65 DNL under the Proposed Action or the Shared-Use Option.

Counts of noise-sensitive receptors are approximate for several reasons, including changes in land use since the aerial photographs were taken (1994 to 2007), and difficulties in determining whether a structure is inhabited or uninhabited. In general, the approach was to count any structure within a noise contour as being inhabited. DOE also examined aerial photographs of portions of the proposed rail alignment not shown in these figures. However, these areas are generally uninhabited and no potential receptors were identified.

I.3 Vibration Analysis Methodology

The vibration analysis methodology is based on Federal Transit Administration methods (DIRS 177297-Hanson, Towers, and Meister 2006, all).

I.3.1 CONSTRUCTION VIBRATION

Vibration due to construction activities, assuming point sources with normal propagation conditions, can be calculated on the basis of the following equation:

$$PPV_{equip} = PPV_{ref} \text{ x } (25/D)^{1\ 5}$$

Where: PPV_{equip} is the peak particle velocity in inches per second of the equipment adjusted for distance.

PPV_{ref} is the reference vibration level of equipment in inches per second at 25 feet.

D is the distance from the equipment to the receptor.

I.3.2 TRAIN VIBRATION

Vibration levels due to trains were estimated on the basis of generalized ground-surface vibration curves, as shown in Figure I-3.

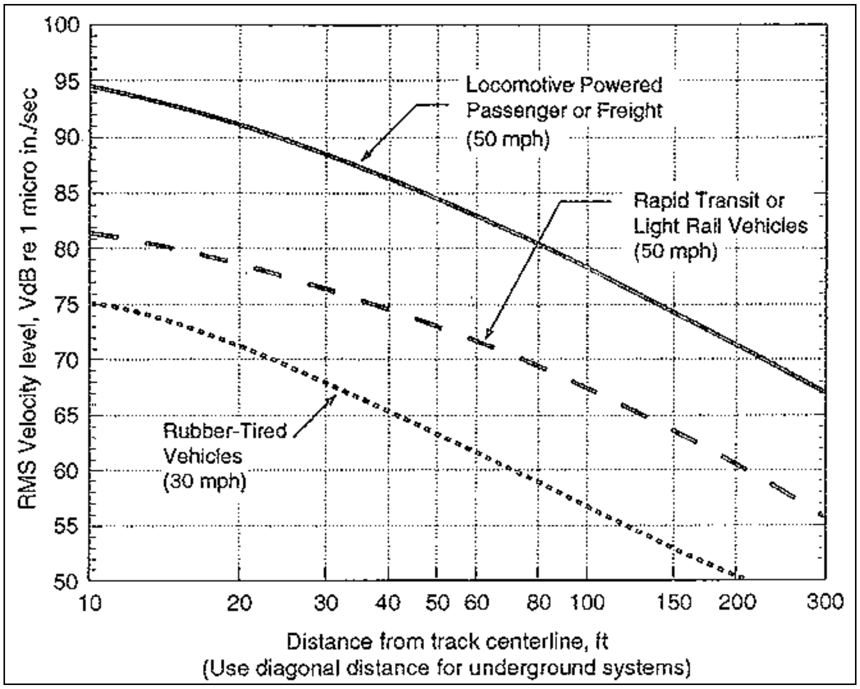


Figure I-3. Generalized ground surface vibration curves.
(Source: DIRS 177297-Hanson, Towers, and Meister 2006. Ft = feet; mph = miles per hour.)

I.4 Glossary

ambient noise	The sum of all sounds (noise is unwanted sound) at a specific location over a specific time.
day-night average noise level	The energy average of ***A-weighted decibel*** sound levels over 24 hours, which 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. The effect of nighttime adjustment is that one nighttime event, such as a train passing by between 10 p.m. and 7 a.m., is equivalent to 10 similar events during the daytime.
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 frequency-weighted noise unit that corresponds approximately to the frequency response of the human ear and thus correlates well with loudness. It is widely used for traffic and industrial noise measurements.
hertz	A unit of frequency equal to one cycle per second.
peak particle velocity	The maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per time (such as millimeters or inches per second). This measurement has been used historically to evaluate shock-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage.
root mean-square velocity	An average or smoothed vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001 (10^{-6}) inch per second and is not to be confused with noise ***decibels***.

I.5 References

178129	DataKustik [n.d.]	DataKustik [n.d.]. Cadna A, Software for Environmental Noise, Computer Aided Noise Abatement. Greifenberg, Germany: DataKustik. TIC: 258792.
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.
174551	DOT 1999	DOT (U.S. Department of Transportation) 1999. Proposed Rule for the Use of Locomotive Horns at Highway-Rail Grade Crossings. Washington, D.C.: U.S. Department of Transportation, Office of Railroad Development. ACC: MOL.20050824.0327.
148155	Hanson, Saurenman, and Towers 1998	Hanson, C.E.; Saurenman, H.J.; and Towers, D.A. 1998. "Rail Transportation Noise and Vibration." Chapter 46 of Handbook of Acoustical Measurements and Noise Control. Harris, C.M., ed. 3rd Edition. New York, New York: McGraw-Hill. TIC: 250744.

177297	Hanson, Towers, and Meister 2006	Hanson, C.E.; Towers, D.A.; and Meister, L.D. 2006. Transit Noise and Vibration Impact Assessment. FTA-VA-90-1003-06. Washington, D.C.: U.S. Department of Transportation, Federal Transit Administration. ACC: MOL.20060814.0190.
174623	Kaiser 1998	Kaiser, E.K. 1998. "Re: Railroad Control Application, Finance Docket No. 33556 — Canadian National — Control — Illinois Central: Release of Draft Environmental Assessment for Public Review and Comment." Letter from E.K. Kaiser (STB) to Interested Parties, November 9, 1998, with enclosure. ACC: MOL.20050824.0324.
174622	STB 1997	STB (Surface Transportation Board) 1997. Before the Surface Transportation Board, Finance Docket No. 33388, CSX Corporation and CSX Transportation, Inc., Norfolk Southern Corporation and Norfolk Southern Railway Company — Control and Operating Leases/Agreements — Conrail Inc. and Consolidated Rail Corporation. Railroad Control Application, Volume 6A of Environmental Report. CSX/NS-23. Washington, D.C.: Surface Transportation Board. ACC: MOL.20060404.0002.
173225	STB 2003	STB (Surface Transportation Board) 2003. Final Environmental Impact Statement, Construction and Operation of a Rail Line from the Bayport Loop in Harris County, Texas. Decision ID No. 33543. Finance Docket No. 34079. [Washington, D.C.]: Surface Transportation Board. ACC: MOL.20050418.0040.

APPENDIX J

SOCIOECONOMICS

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ACRONYMS AND ABBREVIATIONS

DIRS	Document Input Reference System
DOE	U.S. Department of Energy
EIS	environmental impact statement
FEIS	final environmental impact statement
LOS	level of service
REMI	Regional Economic Models, Inc.
SEIS	supplemental environmental impact statement

APPENDIX J

SOCIOECONOMICS

This appendix provides details to support the analysis results reported in Sections 4.2.9 and 4.3.9 of the Rail Alignment EIS.

Section J.2 defines terms shown in ***bold italics***.

J.1 INTRODUCTION

The U.S. Department of Energy (DOE or the Department) used an economic-demographic forecasting model known as *Policy Insight*, developed by Regional Economic Models, Inc. (REMI®) (DIRS 178610-Bland 2007, all), to generate employment, ***real disposable income***, and ***gross regional product*** data for Lyon, Mineral, Clark, Lincoln, Nye, Esmeralda, and Washoe Counties, and Carson City. *Policy Insight* is an eight-region model, seven of the regions being Lyon, Mineral, Clark, Lincoln, Nye, and Esmeralda Counties, and Washoe County-Carson City. Because of the configuration of the DOE version of the model, Carson City and Washoe County are considered as a single economic entity.

The REMI® model has been in use since 1980 to generate year-by-year estimates of the total regional effects of any specific policy initiative. For this analysis DOE used *Policy Insight*, version 9.0 (DIRS 182251-REMI 2007, all). The model has the following features:

- It is calibrated to local conditions using a relatively large amount of local data.
- It combines several different kinds of analytical tools (including economic-base, input-output, and econometric models).
- It allows users to manipulate an unusually large number of input variables and gives forecasts for an unusually large number of output variables.
- It allows users to generate forecasts for any combination of future years, allowing users special flexibility in analyzing the timing of economic impacts.
- It accounts for business cycles.

The description of existing economic conditions in the Caliente and Mina rail alignments regions of influence and the forecast values of populations, gross regional product, and real disposable income draw on data from version 9.0 of *Policy Insight*. The description implicitly includes revenue from the DOE Payments Equal to Taxes program, described in detail in the *Final* (Yucca Mountain FEIS; DIRS 155970-DOE 2002, p. 3-90), and 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* (Repository SEIS DOE/EIS-0250F-51). Revenue from this program is not described separately. Because the model is based on nationally collected data for which there is a lag between collection and issuance by the national agencies, and another lag before the data are incorporated into the *Policy Insight* model, there is always a gap of approximately 2 to 3 years between the current year and the last history year. The year 2004 is the last history year for the *Policy Insight* model (version 9.0) used in this baseline forecast.

To compensate for this time lag, the model's employment update feature is specifically designed to accommodate new historical data provided by users, which update the model's growth-rate assumptions. *Policy Insight* version 9.0 uses an employment update module that relies on data from the Nevada Department of Education, Training, and Rehabilitation for 2004 through 2006. This version also incorporates information from the latest Clark County population projections prepared by the University of Nevada, Las Vegas (DIRS 178806-CBER 2006, all) and the latest population projections developed by the Nevada State Demographer (DIRS 178807-Hardcastle 2006, all).

Impacts are stated in terms of the number of jobs, gross regional product, real disposable income, and state and local government spending. Direct economic effects are the changes in jobs, gross regional product, and income in sectors that would supply directly needed goods and services, such as heavy-duty equipment, during the proposed railroad construction and operations phase.

Items included as *Policy Insight* inputs include direct employment and costs, as follows:

- Employment in the following sectors:
  - Construction
  - Professional and Technical Services
  - Government Employees – Federal Civilian, State and Local
  - Administrative Support Services
  - Food Services
  - Repair and Maintenance
  - Mining (surface mining for quarry sites)
  - Transportation
- For sectors for which wage data for the project are available, wage adjustments on the differential between project wages and model wages are made.
- Costs (increase in demand) for the following sectors are included:
  - Utilities
  - Wholesale Sales
  - Administrative Support Services
  - Construction
  - Mining (surface mining for quarry sites)
  - Accommodations
  - Food Services
  - Repair and Maintenance
  - Professional and Technical Services
  - Transportation

This appendix, in Section J.1.1 through J.1.4, presents results from runs of *Policy Insight* version 9.0 (DIRS 182251-REMI 2007, all) made in March 2007 (DIRS 179558-Bland 2007, all; DIRS 180485-Bland 2007, all) for the Caliente rail alignment and in April 2007 (DIRS 180689-Bland 2007, all) for the Mina rail alignment. As described in Sections 4.2.9 and 4.3.9 of the Rail Alignment EIS, the *Policy Insight* model forecasts changes to baseline economic and demographic conditions that would be associated with the Proposed Action. For the Caliente rail alignment, DOE modeled two scenarios for this analysis, one with the Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (Scenario 1) and one with these facilities in Nye County (Scenario 2). For the Mina rail alignment, DOE modeled two scenarios for this analysis, one with the Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (Scenario 1) and one with these facilities in Nye County (Scenario 2). This appendix provides results for both rail alignments from each scenario for each Nevada county in the socioeconomics ***region of influence*** (for the Caliente rail alignment, Lincoln, Nye, Esmeralda, and Clark Counties; for the Mina rail alignment, Lyon, Mineral, Nye, Esmeralda, and Clark Counties, and Washoe County-Carson City).

This appendix, in Sections J.1.5 through J.1.7, describes the methodology used to quantify impacts to public services, level of service on roadways, and traffic delays at rail-highway grade crossings.

This appendix, in Section J.1.8, presents results for a sensitivity analysis for an optional residency distribution of workers at Yucca Mountain rail facilities near the geologic repository operations area in Nye County.

J.1.1 RAILROAD CONSTRUCTION – CALIENTE RAIL ALIGNMENT

Table J-1 lists percent changes to the baseline that would be associated with the Caliente rail alignment construction phase. The table lists data by county, but does not break the data down by scenario for Esmeralda and Clark Counties because the percent changes would be the same under either scenario. Lincoln and Nye Counties would experience slightly different percent changes under the two scenarios. Rail Alignment EIS Section 3.2.9, Table 3-60, lists baseline numbers. Section 4.2.9, Table 4-101, lists absolute changes to the baseline.

Table J-1. Percent changes from baseline during the construction phase – Caliente rail alignment[a] (page 1 of 2).

	Variable				
Year	Population	Total employment	State and local government spending	Real disposable personal income	Total gross regional product
			Lincoln County		
Scenario 1					
2010	0.89	4.56	1.28	4.11	28.36
2011	1.20	4.67	1.62	2.57	17.29
2012	1.42	5.55	1.87	3.01	19.99
2013	1.50	3.36	1.84	2.31	8.64
2014	1.65	2.86	1.91	2.95	3.83
Scenario 2					
2010	0.87	4.42	1.26	4.06	26.18
2011	1.16	4.67	1.61	2.56	17.29
2012	1.41	5.54	1.86	3.00	19.99
2013	1.49	3.35	1.83	2.31	8.64
2014	1.56	2.41	1.80	2.32	3.35
			Nye County		
Scenario 1					
2010	0.12	1.24	0.33	0.89	3.06
2011	0.13	1.08	0.34	0.56	2.44
2012	0.19	1.36	0.40	0.83	3.50
2013	0.23	0.87	0.36	0.62	2.00
2014	0.23	0.40	0.32	0.32	0.67

Table J-1. Percent changes from baseline during the construction phase – Caliente rail alignment[a] (page 2 of 2).

Year	Population	Total employment	State and local government spending	Real disposable personal income	Total gross regional product
			Nye County *(continued)*		
Scenario 2					
2010	0.12	1.24	0.33	0.89	3.06
2011	0.13	1.08	0.34	0.56	2.44
2012	0.19	1.38	0.40	0.85	3.57
2013	0.24	0.90	0.37	0.64	2.11
2014	0.24	0.42	0.33	0.33	0.71
			Esmeralda County		
2010	0.41	2.73	1.35	7.32	9.47
2011	0.69	2.73	1.79	7.35	1.15
2012	0.91	2.67	2.15	7.57	1.13
2013	0.99	1.92	2.01	4.10	4.47
2014	1.12	1.78	1.95	3.44	1.68
			Clark County		
2010	0.02	0.14	0.02	0.17	0.15
2011	0.03	0.14	0.04	0.17	0.15
2012	0.04	0.14	0.05	0.17	0.15
2013	0.05	0.08	0.05	0.10	0.09
2014	0.04	0.04	0.05	0.06	0.05

a. Sources: DIRS 179558-Bland 2007, all; DIRS 180485-Bland 2007, all.

J.1.2 RAILROAD OPERATIONS – CALIENTE RAIL ALIGNMENT

Tables J-2 through J-5 list impacts associated with the railroad operations phase for the Caliente rail alignment.

Table J-2. Changes from baseline for railroad operations[a] – Caliente rail alignment – Lincoln County (page 1 of 4).

Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County					
2015	102	88	1,001,520	4,148,820	4,414,644
2016	114	89	1,138,761	4,311,450	4,595,292
2017	127	93	1,268,163	4,486,950	6,164,730
2018	136	93	1,375,569	4,609,800	6,415,110
2019	145	94	1,476,657	4,722,120	6,585,930

Table J-2. Changes from baseline for railroad operations[a] – Caliente rail alignment – Lincoln County (page 2 of 4).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (continued)					
2020	153	95	1,560,078	4,819,230	6,781,320
2021	160	95	1,640,340	4,915,170	6,950,970
2022	164	96	1,694,979	4,988,880	7,077,330
2023	167	96	1,734,291	5,048,550	7,176,780
2024	171	96	1,787,643	5,123,430	7,304,310
2025	174	96	1,828,242	5,191,290	7,427,160
2026	177	97	1,865,214	5,260,320	7,557,030
2027	178	97	1,894,113	5,322,330	7,651,800
2028	180	97	1,918,215	5,384,340	7,793,370
2029	181	98	1,947,699	5,451,030	7,933,770
2030	183	98	1,972,620	5,517,720	8,058,960
2031	184	98	1,994,265	5,585,580	8,186,490
2032	185	98	2,014,389	5,655,780	8,288,280
2033	186	99	2,033,109	5,729,490	8,434,530
2034	187	99	2,052,999	5,806,710	8,501,220
2035	187	99	2,068,677	5,882,760	8,542,170
2036	188	99	2,080,026	5,956,470	8,661,510
2037	188	100	2,088,918	6,029,010	8,773,830
2038	187	100	2,093,364	6,102,720	8,877,960
2039	187	100	2,098,863	6,182,280	8,994,960
2040	186	100	2,104,947	6,265,350	9,058,140
2041	185	100	2,101,788	6,342,570	9,009,000
2042	185	100	2,108,808	6,437,340	9,116,640
2043	186	100	2,119,338	6,540,300	9,257,040
2044	185	101	2,122,029	6,638,580	9,390,420
2045	185	101	2,124,252	6,740,370	9,337,770
2046	185	101	2,129,985	6,850,350	9,481,680
2047	186	101	2,140,281	6,973,200	9,637,290
2048	187	101	2,154,906	7,108,920	9,796,410
2049	188	102	2,169,882	7,251,660	9,961,380
2050	189	102	2,187,549	7,400,250	10,129,860
2051	190	102	2,196,324	7,429,933	10,170,492
2052	191	103	2,205,133	7,459,736	10,211,287
2053	191	103	2,213,978	7,489,658	10,252,246
2054	192	104	2,222,859	7,519,700	10,293,369

Table J-2. Changes from baseline for railroad operations[a] – Caliente rail alignment – Lincoln County (page 3 of 4).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (continued)					
2055	193	104	2,231,775	7,549,862	10,334,657
2056	194	105	2,240,727	7,580,146	10,376,111
2057	195	105	2,249,715	7,610,551	10,417,731
2058	195	105	2,258,739	7,641,078	10,459,518
2059	196	106	2,267,799	7,671,727	10,501,472
2060	197	106	2,276,895	7,702,499	10,543,595
2061	198	107	2,286,028	7,733,395	10,585,887
2062	198	107	2,295,198	7,764,415	10,628,348
2063	199	108	2,304,404	7,795,559	10,670,980
2064	200	108	2,313,647	7,826,828	10,713,782
2065	201	108	2,322,928	7,858,222	10,756,757
2066	202	109	2,332,245	7,889,742	10,799,904
2067	202	109	2,341,600	7,921,389	10,843,223
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	88	66	865,952	2,890,066	3,394,153
2016	93	67	928,200	2,956,782	3,490,084
2017	99	70	990,336	3,055,036	4,990,050
2018	103	70	1,039,719	3,115,884	5,181,956
2019	107	71	1,088,399	3,175,589	5,298,965
2020	110	71	1,127,135	3,229,418	5,447,529
2021	114	71	1,166,568	3,286,739	5,571,557
2022	115	71	1,189,968	3,330,055	5,659,334
2023	116	72	1,205,187	3,366,325	5,724,845
2024	118	72	1,230,927	3,413,134	5,811,434
2025	119	72	1,249,652	3,456,441	5,898,005
2026	120	72	1,267,210	3,502,063	5,991,631
2027	121	72	1,280,072	3,543,030	6,051,292
2028	121	72	1,290,606	3,583,989	6,160,128
2029	122	73	1,305,812	3,629,619	6,265,411
2030	122	73	1,318,695	3,675,240	6,355,484
2031	123	73	1,330,399	3,723,193	6,449,127
2032	123	73	1,342,103	3,773,529	6,518,131
2033	124	73	1,353,799	3,826,170	6,631,586
2034	124	73	1,366,669	3,882,391	6,665,560
2035	125	74	1,377,208	3,937,390	6,674,937
2036	125	74	1,386,568	3,992,380	6,764,992

Table J-2. Changes from baseline for railroad operations[a] – Caliente rail alignment – Lincoln County (page 4 of 4).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2037	125	74	1,394,753	4,047,353	6,849,215
2038	125	74	1,399,438	4,101,190	6,925,300
2039	125	74	1,405,288	4,159,707	7,015,407
2040	125	74	1,412,308	4,221,709	7,049,355
2041	125	74	1,414,648	4,281,414	6,975,610
2042	125	74	1,421,672	4,351,648	7,051,695
2043	125	74	1,432,198	4,428,921	7,159,335
2044	126	75	1,439,222	4,504,979	7,264,635
2045	126	75	1,445,068	4,583,378	7,182,700
2046	126	75	1,453,271	4,667,618	7,295,020
2047	127	75	1,463,796	4,760,031	7,414,429
2048	128	75	1,476,662	4,861,786	7,536,075
2049	129	76	1,489,541	4,967,095	7,662,452
2050	130	76	1,503,585	5,075,913	7,790,034
2051	131	76	1,509,616	5,096,273	7,821,281
2052	131	77	1,515,671	5,116,715	7,852,653
2053	132	77	1,521,751	5,137,239	7,884,151
2054	132	77	1,527,855	5,157,845	7,915,776
2055	133	77	1,533,983	5,178,534	7,947,527
2056	133	78	1,540,136	5,199,306	7,979,405
2057	134	78	1,546,314	5,220,161	8,011,412
2058	134	78	1,552,517	5,241,100	8,043,547
2059	135	79	1,558,744	5,262,122	8,075,810
2060	135	79	1,564,996	5,283,229	8,108,204
2061	136	79	1,571,274	5,304,421	8,140,727
2062	136	80	1,577,576	5,325,698	8,173,380
2063	137	80	1,583,904	5,347,060	8,206,165
2064	138	80	1,590,257	5,368,508	8,239,081
2065	138	81	1,596,636	5,390,041	8,272,129
2066	139	81	1,603,040	5,411,661	8,305,309
2067	139	81	1,609,470	5,433,368	8,338,623

a. Sources: DIRS 179558-Bland 2007, all; DIRS 180485-Bland 2007, all.
b. Data expressed in dollars.

Table J-3. Changes from baseline for railroad operations[a] – Caliente rail alignment – Nye County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County					
2015	143	56	617,270	3,587,624	7,035,854
2016	149	53	647,337	3,463,212	7,037,582
2017	154	54	675,180	3,446,165	7,775,518
2018	159	54	700,701	3,451,968	8,083,646
2019	163	55	724,280	3,483,277	8,349,515
2020	167	56	746,807	3,537,518	8,674,915
2021	171	58	768,362	3,607,239	8,974,574
2022	174	59	788,982	3,682,680	9,252,561
2023	178	61	809,415	3,761,070	9,509,683
2024	181	62	828,678	3,846,761	9,768,114
2025	184	63	846,988	3,930,861	10,025,514
2026	187	64	864,980	4,017,722	10,282,161
2027	190	65	881,781	4,105,752	10,501,982
2028	192	66	898,066	4,198,264	10,771,362
2029	195	67	914,468	4,289,665	11,029,737
2030	197	67	929,901	4,383,487	11,265,186
2031	199	68	944,747	4,482,375	11,504,339
2032	201	69	958,939	4,584,306	11,717,697
2033	203	70	972,732	4,692,086	11,963,537
2034	205	70	987,076	4,797,725	12,139,316
2035	207	71	1,001,103	4,901,715	12,279,437
2036	209	71	1,015,143	5,013,146	12,502,016
2037	211	72	1,030,038	5,130,696	12,736,016
2038	213	73	1,044,967	5,251,487	12,958,873
2039	215	73	1,060,563	5,377,659	13,204,573
2040	218	74	1,076,042	5,503,259	13,380,353
2041	220	74	1,091,321	5,634,252	13,451,389
2042	222	75	1,106,449	5,769,130	13,673,411
2043	224	75	1,121,846	5,913,320	13,930,531
2044	227	76	1,137,359	6,061,852	14,189,047
2045	229	77	1,152,569	6,211,565	14,247,826
2046	232	77	1,168,504	6,370,627	14,505,506
2047	235	78	1,184,451	6,539,107	14,787,421
2048	238	78	1,199,766	6,718,339	15,068,221
2049	240	79	1,216,215	6,904,041	15,349,300
2050	243	80	1,231,530	7,094,751	15,643,473
2051	247	81	1,248,771	7,194,076	15,862,478

Table J-3. Changes from baseline for railroad operations[a] – Caliente rail alignment – Nye County (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (continued)					
2052	250	82	1,266,254	7,294,792	16,084,549
2053	254	83	1,283,981	7,396,917	16,309,729
2054	257	84	1,301,957	7,500,472	16,538,062
2055	261	86	1,320,184	7,605,477	16,769,591
2056	265	87	1,338,666	7,711,952	17,004,361
2057	268	88	1,357,407	7,819,917	17,242,418
2058	272	89	1,376,410	7,929,394	17,483,808
2059	276	90	1,395,680	8,040,404	17,728,577
2060	280	92	1,415,219	8,152,968	17,967,773
2061	284	93	1,435,032	8,267,108	18,228,444
2062	288	94	1,455,122	8,382,845	18,483,638
2063	292	96	1,475,493	8,500,203	18,742,405
2064	296	97	1,496,150	8,619,204	19,004,794
2065	300	98	1,517,096	8,739,871	19,270,857
2066	304	100	1,538,335	8,862,227	19,540,644
2067	308	101	1,559,871	8,986,296	19,814,209
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	148	59	638,317	3,761,433	7,505,082
2016	154	56	671,990	3,640,104	7,517,835
2017	160	57	703,041	3,625,830	8,266,986
2018	166	58	731,507	3,635,892	8,588,151
2019	170	59	757,786	3,671,694	8,866,845
2020	175	60	782,777	3,731,130	9,205,911
2021	179	62	806,610	3,805,191	9,519,237
2022	183	63	829,378	3,885,921	9,811,269
2023	187	65	851,830	3,969,576	10,083,060
2024	191	66	872,925	4,061,421	10,356,138
2025	194	67	892,979	4,150,809	10,627,461
2026	197	68	912,542	4,243,239	10,897,848
2027	200	69	930,946	4,336,956	11,131,848
2028	203	70	948,659	4,435,119	11,415,456
2029	206	71	966,420	4,532,346	11,687,481
2030	208	72	983,151	4,630,626	11,936,808
2031	210	73	999,110	4,735,107	12,190,230
2032	213	73	1,014,449	4,842,747	12,417,327
2033	215	74	1,029,261	4,955,652	12,677,535
2034	217	75	1,044,611	5,067,855	12,867,075

Table J-3. Changes from baseline for railroad operations[a] – Caliente rail alignment – Nye County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2035	219	75	1,059,611	5,178,303	13,021,749
2036	221	76	1,074,598	5,296,005	13,258,791
2037	224	77	1,090,463	5,420,142	13,507,533
2038	226	77	1,106,340	5,548,140	13,745,745
2039	228	78	1,122,908	5,680,584	14,006,304
2040	230	79	1,139,288	5,812,560	14,197,716
2041	233	79	1,155,515	5,951,673	14,283,477
2042	235	80	1,171,509	6,095,817	14,521,689
2043	238	80	1,187,784	6,247,215	14,794,767
2044	240	81	1,204,129	6,403,527	15,067,962
2045	243	81	1,220,252	6,561,126	15,143,778
2046	246	82	1,236,983	6,728,553	15,417,675
2047	249	83	1,253,807	6,905,925	15,716,844
2048	251	83	1,270,023	7,093,242	16,014,141
2049	255	84	1,287,351	7,288,398	16,312,491
2050	258	85	1,303,462	7,490,574	16,623,126
2051	261	86	1,321,710	7,595,440	16,855,846
2052	265	87	1,340,214	7,701,775	17,091,824
2053	269	88	1,358,976	7,809,598	17,331,105
2054	272	90	1,378,002	7,918,930	17,573,737
2055	276	91	1,397,293	8,029,794	17,819,765
2056	280	92	1,416,855	8,142,209	18,069,238
2057	284	94	1,436,691	8,256,198	18,322,203
2058	288	95	1,456,804	8,371,783	18,578,709
2059	292	96	1,477,199	8,488,986	18,838,807
2060	296	98	1,497,880	8,607,830	19,102,546
2061	300	99	1,518,850	8,728,337	19,369,977
2062	304	100	1,540,113	8,850,532	19,641,152
2063	309	102	1,561,674	8,974,437	19,916,124
2064	313	103	1,583,537	9,100,077	20,194,945
2065	317	105	1,605,707	9,227,476	20,477,670
2066	322	106	1,628,186	9,356,659	20,764,352
2067	326	108	1,650,980	9,487,650	21,055,049

a. Sources: DIRS 179558-Bland 2007, all; DIRS 180485-Bland 2007, all.

b. Data expressed in dollars.

Table J-4. Changes from baseline for railroad operations[a] – Caliente rail alignment – Esmeralda County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County					
2015	14	11	124,992	895,739	701,737
2016	15	11	136,313	893,335	728,820
2017	16	11	144,510	894,511	755,607
2018	16	11	152,480	897,486	784,038
2019	17	12	159,981	902,288	813,518
2020	18	12	164,562	908,345	842,297
2021	18	12	170,427	916,626	872,824
2022	18	12	174,891	924,740	903,235
2023	19	12	179,358	933,682	934,366
2024	19	12	183,473	943,101	965,962
2025	19	12	187,003	952,491	997,910
2026	20	12	190,297	962,240	1,030,325
2027	20	13	193,123	972,228	1,063,083
2028	20	13	195,949	984,080	1,096,320
2029	20	13	198,655	995,349	1,130,029
2030	20	13	201,129	1,006,523	1,164,310
2031	20	13	203,601	1,018,011	1,199,533
2032	21	13	205,837	1,029,759	1,235,819
2033	21	13	207,838	1,041,843	1,272,097
2034	21	13	209,722	1,053,825	1,309,553
2035	21	13	211,253	1,065,446	1,346,993
2036	21	13	212,784	1,077,306	1,386,779
2037	21	13	214,314	1,089,716	1,426,590
2038	21	13	215,608	1,102,758	1,466,372
2039	21	13	217,253	1,116,247	1,508,500
2040	21	13	218,662	1,130,344	1,551,804
2041	21	13	219,956	1,144,791	1,595,102
2042	21	13	221,014	1,159,815	1,639,567
2043	21	13	221,836	1,169,539	1,685,205
2044	21	13	222,425	1,178,575	1,730,835
2045	21	13	222,778	1,189,156	1,777,661
2046	21	13	223,013	1,195,033	1,825,631
2047	21	13	223,129	1,212,666	1,874,780
2048	21	13	223,131	1,231,468	1,925,099
2049	21	14	223,013	1,251,441	1,976,596
2050	21	14	222,660	1,258,527	2,028,081
2051	21	14	223,088	1,260,945	2,031,977

Table J-4. Changes from baseline for railroad operations[a] – Caliente rail alignment – Esmeralda County (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (continued)					
2052	21	14	223,517	1,263,367	2,035,881
2053	21	14	223,946	1,265,795	2,039,793
2054	21	14	224,376	1,268,227	2,043,711
2055	21	14	224,808	1,270,663	2,047,638
2056	21	14	225,239	1,273,104	2,051,572
2057	21	14	225,672	1,275,550	2,055,514
2058	21	14	226,106	1,278,001	2,059,463
2059	21	14	226,540	1,280,456	2,063,419
2060	21	14	226,975	1,282,916	2,067,384
2061	21	14	227,411	1,285,381	2,071,356
2062	21	14	227,848	1,287,851	2,075,535
2063	22	14	228,286	1,290,325	2,079,323
2064	22	14	228,725	1,292,804	2,083,317
2065	22	14	229,164	1,295,288	2,087,320
2066	22	14	229,604	1,297,776	2,091,330
2067	22	14	230,046	1,300,270	2,095,348
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	14	11	125,053	895,279	701,735
2016	15	11	136,330	892,489	728,784
2017	16	11	144,525	893,387	755,563
2018	16	11	152,488	896,190	783,994
2019	17	12	159,981	900,867	813,476
2020	18	12	164,550	906,842	842,263
2021	18	12	170,403	915,050	872,789
2022	18	12	174,852	923,148	903,204
2023	19	12	179,305	932,078	934,331
2024	19	12	183,406	941,478	965,938
2025	19	12	186,921	950,866	997,877
2026	20	12	190,202	960,607	1,030,297
2027	20	13	193,015	970,600	1,063,048
2028	20	13	195,829	982,443	1,096,281
2029	20	13	198,525	993,717	1,129,985
2030	20	13	200,987	1,004,888	1,164,273
2031	20	13	203,450	1,016,392	1,199,496
2032	21	13	205,679	1,028,145	1,235,768
2033	21	13	207,672	1,040,224	1,272,045
2034	21	13	209,549	1,052,208	1,309,498

Table J-4. Changes from baseline for railroad operations[a] – Caliente rail alignment – Esmeralda County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2035	21	13	211,074	1,063,834	1,346,936
2036	21	13	212,600	1,075,697	1,386,716
2037	21	13	214,125	1,088,147	1,426,524
2038	21	13	215,416	1,101,202	1,466,302
2039	21	13	217,058	1,114,713	1,508,413
2040	21	13	218,467	1,128,814	1,551,725
2041	21	13	219,759	1,143,266	1,595,204
2042	21	13	220,816	1,158,289	1,639,493
2043	21	13	221,639	1,168,040	1,685,123
2044	21	13	222,228	1,177,088	1,730,761
2045	21	13	222,582	1,187,680	1,777,574
2046	21	13	222,820	1,193,556	1,825,544
2047	21	13	222,938	1,211,162	1,874,689
2048	21	13	222,942	1,229,957	1,924,994
2049	21	14	222,827	1,249,907	1,976,496
2050	21	14	222,477	1,256,975	2,027,980
2051	21	14	222,905	1,259,390	2,031,877
2052	21	14	223,333	1,261,810	2,035,780
2053	21	14	223,762	1,264,234	2,039,692
2054	21	14	224,192	1,266,663	2,043,610
2055	21	14	224,623	1,269,097	2,047,537
2056	21	14	225,054	1,271,535	2,051,471
2057	21	14	225,487	1,273,978	2,055,412
2058	21	14	225,920	1,276,426	2,059,361
2059	21	14	226,354	1,278,878	2,063,317
2060	21	14	226,789	1,281,335	2,067,282
2061	21	14	227,225	1,283,797	2,071,253
2062	21	14	227,661	1,286,263	2,075,223
2063	22	14	228,099	1,288,734	2,079,220
2064	22	14	228,537	1,291,210	2,083,214
2065	22	14	228,976	1,293,691	2,087,217
2066	22	14	229,416	1,296,177	2,091,227
2067	22	14	229,857	1,298,667	2,095,245

a. Sources: DIRS 179558-Bland 2007, all; DIRS 180485-Bland 2007, all.
b. Data expressed in dollars.

Table J-5. Changes from baseline for railroad operations[a] – Caliente rail alignment – Clark County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County					
2015	1008	74	4,087,278	13,340,457	10,872,342
2016	900	23	3,678,726	10,452,897	5,507,307
2017	798	1	3,288,905	8,488,935	2,705,040
2018	709	-3	2,937,741	7,346,898	1,704,924
2019	631	3	2,632,044	6,730,425	1,740,375
2020	563	13	2,364,008	6,533,748	2,320,344
2021	505	24	2,135,695	6,462,261	3,311,451
2022	457	36	1,941,311	6,703,281	4,195,854
2023	416	47	1,778,576	6,998,355	5,338,476
2024	382	57	1,641,522	7,311,096	6,301,620
2025	352	64	1,518,672	7,605,819	7,122,726
2026	326	71	1,416,718	7,909,083	7,801,326
2027	304	76	1,323,059	8,096,283	8,480,511
2028	283	79	1,241,113	8,363,745	8,890,245
2029	264	83	1,167,169	8,613,657	9,390,771
2030	249	85	1,102,362	8,801,676	9,712,170
2031	234	88	1,043,277	8,944,065	10,122,606
2032	222	89	994,196	9,221,355	10,586,511
2033	212	90	953,948	9,408,204	10,818,405
2034	204	91	921,656	9,702,576	11,229,777
2035	199	92	903,825	9,908,145	11,336,130
2036	195	93	885,912	10,140,741	11,640,096
2037	192	94	883,701	10,372,050	11,818,755
2038	192	94	884,871	10,631,439	12,228,957
2039	193	94	893,751	10,783,188	12,335,895
2040	197	94	912,717	11,050,533	12,694,968
2041	200	94	933,941	11,283,363	12,798,981
2042	206	95	958,511	11,568,141	13,173,966
2043	210	96	990,873	11,862,747	13,407,966
2044	218	96	1,023,165	12,256,569	13,830,453
2045	225	98	1,063,413	12,789,270	14,269,437
2046	234	99	1,104,656	13,339,755	14,725,737
2047	242	101	1,150,356	13,960,440	15,287,337
2048	251	105	1,191,715	14,516,424	15,991,209
2049	259	107	1,234,022	15,101,424	16,675,308
2050	267	110	1,267,473	15,927,210	17,496,180
2051	269	111	1,281,157	16,099,174	17,685,084

Table J-5. Changes from baseline for railroad operations[a] – Caliente rail alignment – Clark County (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (continued)					
2052	272	112	1,294,990	16,272,994	17,876,027
2053	275	113	1,308,972	16,448,691	18,069,032
2054	278	115	1,323,104	16,626,285	18,264,120
2055	281	116	1,337,390	16,805,797	18,461,315
2056	284	117	1,351,829	16,987,247	18,660,640
2057	287	118	1,366,425	17,170,655	18,862,116
2058	290	120	1,381,178	17,356,044	19,065,767
2059	294	121	1,396,090	17,543,435	19,271,617
2060	297	122	1,411,164	17,732,849	19,479,690
2061	300	124	1,426,400	17,924,308	19,690,010
2062	303	125	1,441,801	18,117,834	19,902,600
2063	307	126	1,457,367	18,313,450	20,117,485
2064	310	128	1,473,102	18,511,177	20,334,691
2065	313	129	1,489,007	18,711,040	20,554,241
2066	317	130	1,505,084	18,913,060	20,776,162
2067	320	132	1,521,334	19,117,262	21,000,480
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	1014	81	4,108,478	13,956,345	11,675,781
2016	907	30	3,707,742	11,113,479	6,248,151
2017	807	8	3,324,602	9,194,094	3,427,983
2018	719	3	2,980,142	8,034,273	2,356,614
2019	641	8	2,677,791	7,471,386	2,365,272
2020	575	18	2,415,336	7,230,015	2,972,034
2021	519	29	2,190,369	7,158,411	3,918,330
2022	471	41	2,001,566	7,426,224	4,891,770
2023	431	52	1,841,054	7,703,514	6,017,310
2024	397	62	1,708,469	8,034,156	6,997,770
2025	368	70	1,587,807	8,337,771	7,854,210
2026	343	77	1,487,070	8,650,044	8,586,630
2027	320	81	1,395,576	8,801,442	9,230,130
2028	300	85	1,316,952	9,095,814	9,711,000
2029	282	89	1,244,178	9,327,708	10,211,760
2030	266	91	1,179,360	9,524,736	10,551,060
2031	252	94	1,122,498	9,711,819	10,996,830
2032	240	95	1,073,475	10,015,902	11,497,590
2033	231	97	1,037,673	10,184,733	11,764,350
2034	223	98	1,006,434	10,470,213	12,230,010

Table J-5. Changes from baseline for railroad operations[a] – Caliente rail alignment – Clark County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2035	219	99	991,926	10,738,260	12,407,850
2036	215	100	975,195	10,970,856	12,675,780
2037	212	100	972,972	11,237,850	12,889,890
2038	212	101	976,365	11,505,780	13,424,580
2039	213	101	988,650	11,649,105	13,549,770
2040	217	102	1,007,604	11,916,450	13,855,140
2041	221	102	1,031,004	12,193,740	14,066,910
2042	226	103	1,056,744	12,487,410	14,495,130
2043	232	103	1,091,259	12,737,790	14,746,680
2044	239	104	1,123,551	13,130,910	15,205,320
2045	247	105	1,166,022	13,691,340	15,608,970
2046	256	107	1,207,323	14,214,330	16,225,560
2047	264	109	1,250,730	14,835,600	16,787,160
2048	273	113	1,296,594	15,445,170	17,490,330
2049	281	115	1,336,725	16,030,170	18,174,780
2050	289	118	1,374,633	16,837,470	19,138,860
2051	292	120	1,389,475	17,019,262	19,345,499
2052	295	121	1,404,477	17,203,016	19,554,370
2053	298	122	1,419,641	17,388,755	19,765,496
2054	302	123	1,434,968	17,576,498	19,978,901
2055	305	125	1,450,461	17,766,269	20,194,610
2056	308	126	1,466,122	17,958,089	20,412,648
2057	312	128	1,481,951	18,151,980	20,633,041
2058	315	129	1,497,952	18,347,964	20,855,812
2059	318	130	1,514,125	18,546,064	21,080,990
2060	322	132	1,530,473	18,746,304	21,308,598
2061	325	133	1,546,997	18,948,705	21,538,664
2062	329	135	1,563,700	19,153,291	21,771,213
2063	332	136	1,580,583	19,360,086	22,006,274
2064	336	137	1,597,648	19,569,114	22,243,873
2065	340	139	1,614,898	19,780,399	22,484,036
2066	343	140	1,632,333	19,993,965	22,726,793
2067	347	142	1,649,957	20,209,837	22,972,171

a. Sources: DIRS 179558-Bland 2007, all; DIRS 180485-Bland 2007, all.
b. Data expressed in dollars.

J.1.3 RAILROAD CONSTRUCTION – MINA RAIL ALIGNMENT

Table J-6 lists percent changes to the baseline that would be associated with the Mina rail alignment construction phase. The table lists data by county, but does not break the data down by scenario for Lyon, Esmeralda, and Clark Counties because the percent changes would be the same under either scenario. Mineral and Nye Counties would experience slightly different percent changes under the two scenarios. Section 3.3.9, Table 3-60, lists baseline numbers. Rail Alignment EIS Section 4.3.9, Table 4-245, lists absolute changes to the baseline. As a sensitivity analysis, the socioeconomic analysis for the Mina rail alignment assesses the impacts of the project's construction phase on the combined area of Washoe County-Carson City. This alternative analysis assumes that 50 percent of the construction workers come from the Washoe County-Carson City area. Table J-7 includes percent changes to the baseline for this combined area.

Table J-6. Percent changes from baseline for railroad construction – Mina rail alignment[a] (page 1 of 2).

	Variable				
Year	Population	Total employment	State and local government spending	Real disposable personal income	Total gross regional product
Lyon County					
2010	0.00	0.02	0.00	0.02	0.04
2011	0.01	0.02	0.01	0.03	0.02
2012	0.01	0.02	0.01	0.03	0.02
2013	0.01	0.01	0.01	0.02	0.01
2014	0.01	0.01	0.01	0.01	0.01
Mineral County					
Scenario 1					
2010	0.75	4.87	1.19	3.72	1.63
2011	1.08	5.36	1.53	4.19	13.97
2012	1.36	6.09	1.76	4.47	14.13
2013	1.36	3.47	1.45	2.62	7.21
2014	1.33	2.25	1.32	1.83	1.72
Scenario 2					
2010	0.74	4.78	1.18	3.70	1.52
2011	1.08	5.36	1.52	4.18	13.97
2012	1.35	6.09	1.75	4.47	14.13
2013	1.35	3.47	1.45	2.62	7.21
2014	1.27	1.87	1.27	1.42	1.52
Nye County					
Scenario 1					
2010	0.04	0.42	0.12	0.29	0.58
2011	0.05	0.34	0.12	0.14	0.36
2012	0.09	0.54	0.16	0.32	0.80
2013	0.14	0.54	0.17	0.38	0.93
2014	0.15	0.19	0.16	0.17	0.27

Table J-6. Percent changes from baseline for railroad construction – Mina rail alignment[a] (page 2 of 2).

Year	Population	Total employment	State and local government spending	Real disposable personal income	Total gross regional product
			Nye County *(continued)*		
Scenario 2					
2010	0.04	0.34	0.13	0.15	0.37
2011	0.10	0.55	0.17	0.33	0.83
2012	0.15	0.56	0.18	0.40	1.02
2013	0.16	0.22	0.17	0.19	0.38
2014	0.15	0.09	0.16	0.12	0.15
			Esmeralda County		
2010	0.45	5.655	2.70	17.63	27.52
2011	0.68	6.136	3.04	17.90	10.03
2012	1.62	13.85	4.36	27.15	56.67
2013	2.46	11.07	4.10	18.78	53.00
2014	3.08	10.70	4.61	15.22	41.35
			Clark County		
2010	0.02	0.14	0.02	0.14	0.13
2011	0.03	0.14	0.03	0.14	0.13
2012	0.04	0.14	0.04	0.14	0.13
2013	0.04	0.06	0.04	0.06	0.06
2014	0.04	0.03	0.04	0.04	0.03

a. Sources: DIRS 182251-REMI 2007, all; DIRS 179558-Bland 2007, all; DIRS 180690-Bland 2007, all; DIRS 180689-Bland 2007 all.

Table J-7. Percent changes from baseline on Washoe County-Carson City for railroad construction – Mina rail alignment.[a]

Year	Population	Total employment	State and local government spending	Real disposable personal income	Total gross regional product
			Washoe County-Carson City		
2010	0.03	0.24	0.03	0.24	0.20
2011	0.06	0.24	0.06	0.24	0.21
2012	0.07	0.23	0.08	0.24	0.20
2013	0.07	0.08	0.07	0.09	0.07
2014	0.06	0.05	0.07	0.06	0.04

a. Source: DIRS 181590-Bland 2007, all.

J.1.4 RAILROAD OPERATIONS – MINA RAIL ALIGNMENT

Tables J-8 through J-12 list impacts associated with the railroad operations phase for the Mina rail alignment, and Table J-13 lists the results of the alternative analysis for the combined area of Washoe County-Carson City.

Table J-8. Changes from baseline for railroad operations[a] – Mina rail alignment – Lyon County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County					
2015	8	1	34,972	123,575	54,815
2016	8	1	35,669	121,762	51,188
2017	8	1	36,330	125,120	52,018
2018	8	1	36,956	126,079	52,861
2019	8	1	37,454	127,331	54,534
2020	8	1	37,799	129,425	56,066
2021	8	1	38,251	130,829	58,851
2022	8	1	38,423	132,643	60,945
2023	8	1	38,770	135,568	62,618
2024	8	1	39,187	137,101	64,724
2025	8	1	39,407	140,306	66,807
2026	8	1	39,789	143,372	69,603
2027	8	1	40,068	146,028	71,136
2028	9	1	40,241	148,262	72,809
2029	9	1	40,484	151,609	74,623
2030	9	1	40,693	155,926	76,296
2031	9	1	41,042	158,582	80,344
2032	9	1	41,286	162,630	81,175
2033	9	1	41,460	165,695	81,877
2034	9	1	41,705	169,287	86,054
2035	9	1	42,015	172,493	88,569
2036	9	1	42,260	174,342	89,681
2037	9	1	42,541	177,723	91,213
2038	9	1	43,033	183,866	94,010
2039	9	1	43,477	186,908	95,402
2040	9	1	43,934	190,219	99,017
2041	9	1	44,249	193,916	101,825
2042	9	1	44,706	198,374	103,206
2043	9	1	45,057	200,012	105,721
2044	9	1	45,607	207,558	109,348
2045	9	1	46,238	211,396	113,818
2046	9	1	46,800	218,685	116,602
2047	9	1	47,455	227,390	122,171
2048	9	1	48,075	234,070	123,856
2049	10	1	48,777	243,278	128,876
2050	10	1	49,339	249,959	134,164

Table J-8. Changes from baseline for railroad operations[a] – Mina rail alignment – Lyon County (page 2 of 3).

Year	Variable				
	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (continued)					
2051	10	1	50,128	253,958	136,311
2052	10	1	50,930	258,021	138,491
2053	10	1	51,745	262,150	140,707
2054	10	1	52,573	266,344	142,959
2055	10	1	53,414	270,606	145,246
2056	11	1	54,269	274,935	147,570
2057	11	2	55,137	279,334	149,931
2058	11	2	56,019	283,804	152,330
2059	11	2	56,916	288,344	154,767
2060	11	2	57,826	292,958	157,243
2061	11	2	58,752	297,645	159,759
2062	12	2	59,692	302,407	162,315
2063	12	2	60,647	307,246	164,912
2064	12	2	61,617	312,162	167,551
2065	12	2	62,603	317,156	170,232
2066	12	2	63,605	322,231	172,955
2067	13	2	64,622	327,386	175,723
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	8	1	33,543	104,187	43,101
2016	8	1	33,333	99,168	37,241
2017	7	1	33,122	100,148	36,679
2018	7	1	32,876	99,305	36,398
2019	7	1	32,572	99,023	37,798
2020	7	1	32,186	99,303	38,631
2021	7	1	31,975	99,445	40,582
2022	7	1	31,589	100,565	42,257
2023	7	1	31,378	102,517	43,510
2024	7	1	31,272	103,069	45,614
2025	7	1	31,108	104,881	47,007
2026	7	1	30,968	106,553	49,098
2027	7	1	30,897	108,926	49,791
2028	7	1	30,722	110,327	51,193
2029	6	1	30,721	112,978	52,863
2030	6	1	30,581	116,039	54,116
2031	6	1	30,825	118,274	56,770
2032	6	1	30,790	120,509	58,018

Table J-8. Changes from baseline for railroad operations[a] – Mina rail alignment – Lyon County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2033	6	1	30,825	123,011	57,743
2034	6	1	30,895	125,914	61,505
2035	6	1	31,000	128,276	62,210
2036	6	1	31,140	130,126	63,041
2037	6	1	31,351	132,677	64,153
2038	6	1	31,631	136,723	66,388
2039	6	1	31,936	139,760	67,508
2040	6	1	32,251	142,524	70,012
2041	6	1	32,497	144,818	71,416
2042	7	1	32,813	148,445	71,690
2043	7	1	33,059	150,641	74,483
2044	7	1	33,469	155,952	76,437
2045	7	1	34,065	159,785	80,339
2046	7	1	34,521	165,680	82,293
2047	7	1	34,978	171,602	87,028
2048	7	1	35,492	176,885	87,037
2049	7	1	35,984	183,581	91,770
2050	7	1	36,475	189,152	94,837
2051	7	1	36,208	186,510	94,087
2052	7	1	36,788	189,494	95,593
2053	7	1	37,376	192,526	97,122
2054	7	1	37,974	195,607	98,676
2055	8	1	38,582	198,736	100,255
2056	8	1	39,199	201,916	101,859
2057	8	1	39,826	205,147	103,489
2058	8	1	40,464	208,429	105,144
2059	8	1	41,111	211,764	106,827
2060	8	1	41,769	215,152	108,536
2061	8	1	42,437	218,594	110,272
2062	8	1	43,116	222,092	112,037
2063	9	1	43,806	225,645	113,829
2064	9	1	44,507	229,256	115,651
2065	9	1	45,219	232,924	117,501
2066	9	1	45,942	236,651	119,381
2067	9	1	46,678	240,437	121,291

a. Sources: DIRS 182251-REMI 2007, all; DIRS 179558-Bland 2007, all; DIRS 180690-Bland 2007, all; DIRS 180689-Bland 2007, all.
b. Data expressed in dollars.

Table J-9. Changes from baseline for railroad operations[a] – Mina rail alignment – Mineral County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County					
2015	66	63	534,362	3,033,927	2,168,478
2016	68	62	552,813	3,081,312	2,170,584
2017	70	65	575,172	3,185,442	3,698,253
2018	71	64	593,307	3,222,063	3,809,754
2019	73	63	608,283	3,250,260	3,842,514
2020	74	63	618,930	3,274,830	3,915,288
2021	74	62	628,290	3,297,060	3,961,035
2022	75	62	634,257	3,315,780	3,986,424
2023	75	61	638,469	3,333,330	3,997,188
2024	75	61	641,511	3,349,710	4,019,652
2025	74	61	642,330	3,364,920	4,047,498
2026	74	60	641,979	3,380,130	4,081,194
2027	73	60	640,107	3,394,170	4,087,746
2028	73	60	637,767	3,409,380	4,146,246
2029	72	60	634,257	3,423,420	4,194,567
2030	71	59	630,279	3,438,630	4,229,082
2031	70	59	625,716	3,456,180	4,268,043
2032	69	59	621,387	3,474,900	4,280,445
2033	69	59	617,058	3,494,790	4,337,424
2034	68	59	613,548	3,517,020	4,316,013
2035	67	58	610,272	3,539,250	4,266,171
2036	67	58	607,464	3,561,480	4,303,494
2037	66	58	605,826	3,584,880	4,333,563
2038	66	58	604,422	3,609,450	4,360,239
2039	65	58	603,486	3,635,190	4,399,785
2040	65	58	603,018	3,663,270	4,378,842
2041	64	57	602,316	3,690,180	4,252,950
2042	64	57	601,848	3,720,600	4,273,074
2043	64	57	601,497	3,752,190	4,318,353
2044	64	57	601,380	3,786,120	4,367,376
2045	64	57	600,678	3,820,050	4,225,104
2046	63	57	600,093	3,857,490	4,275,531
2047	63	57	599,508	3,897,270	4,327,362
2048	63	57	598,923	3,940,560	4,382,820
2049	63	57	597,987	3,983,850	4,438,863
2050	63	57	596,466	4,027,140	4,496,544

Table J-9. Changes from baseline for railroad operations[a] – Mina rail alignment – Mineral County (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (continued)					
2051	62	57	594,075	4,010,998	4,478,521
2052	62	56	591,694	3,994,922	4,460,570
2053	62	56	589,322	3,978,909	4,442,691
2054	62	56	586,960	3,962,961	4,424,884
2055	61	56	584,608	3,947,077	4,407,148
2056	61	55	582,264	3,931,256	4,389,484
2057	61	55	579,931	3,915,499	4,371,890
2058	61	55	577,606	3,899,804	4,354,366
2059	60	55	575,291	3,884,173	4,336,913
2060	60	55	572,985	3,868,605	4,319,530
2061	60	54	570,688	3,853,099	4,302,216
2062	60	54	568,401	3,837,655	4,284,972
2063	59	54	566,123	3,822,273	4,267,797
2064	59	54	563,854	3,806,952	4,250,691
2065	59	53	561,594	3,791,693	4,233,653
2066	59	53	559,343	3,776,495	4,216,684
2067	59	53	557,101	3,761,358	4,199,783
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	58	44	469,946	2,012,871	1,530,465
2016	55	44	453,939	1,997,687	1,519,952
2017	54	46	446,230	2,055,043	3,042,087
2018	53	45	438,170	2,056,248	3,150,949
2019	51	45	430,344	2,057,461	3,182,539
2020	50	45	421,704	2,060,980	3,253,892
2021	49	45	414,341	2,065,651	3,297,165
2022	48	44	406,520	2,071,501	3,319,429
2023	47	44	399,157	2,077,369	3,325,349
2024	46	44	392,385	2,084,424	3,341,677
2025	45	43	385,248	2,091,418	3,362,737
2026	43	43	378,236	2,098,464	3,388,494
2027	42	43	371,099	2,105,501	3,386,154
2028	41	43	364,318	2,113,674	3,435,347
2029	40	43	357,298	2,120,711	3,473,887
2030	39	42	350,759	2,128,919	3,498,544
2031	39	42	344,441	2,139,449	3,527,794
2032	38	42	338,955	2,151,140	3,530,099

Table J-9. Changes from baseline for railroad operations[a] – Mina rail alignment – Mineral County (page 3 of 3).

Year	Variable				
	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2033	37	42	334,158	2,164,036	3,576,951
2034	36	42	330,301	2,178,102	3,545,379
2035	36	41	327,029	2,193,347	3,485,691
2036	36	41	324,451	2,207,335	3,512,619
2037	35	41	322,813	2,222,527	3,532,561
2038	35	41	321,652	2,237,737	3,548,837
2039	35	41	321,179	2,254,135	3,578,156
2040	34	41	320,950	2,271,755	3,546,584
2041	34	41	320,720	2,289,287	3,409,764
2042	34	41	320,841	2,309,195	3,419,019
2043	34	40	321,084	2,330,324	3,452,984
2044	34	40	321,669	2,353,742	3,490,459
2045	34	40	321,899	2,377,177	3,337,154
2046	34	40	322,029	2,402,951	3,375,834
2047	34	40	322,033	2,431,031	3,415,544
2048	34	40	321,929	2,461,521	3,458,938
2049	34	40	321,353	2,490,789	3,502,194
2050	34	40	320,304	2,519,986	3,546,654
2051	33	40	318,712	2,508,913	3,532,056
2052	33	40	317,435	2,498,857	3,517,899
2053	33	40	316,163	2,488,841	3,503,798
2054	33	39	314,895	2,478,865	3,489,754
2055	33	39	313,633	2,468,930	3,475,767
2056	33	39	312,376	2,459,034	3,461,835
2057	33	39	311,124	2,449,177	3,447,959
2058	33	39	309,877	2,439,361	3,434,139
2059	32	39	308,635	2,429,583	3,420,375
2060	32	39	307,398	2,419,845	3,406,665
2061	32	38	306,166	2,410,146	3,393,010
2062	32	38	304,939	2,400,485	3,379,411
2063	32	38	303,716	2,390,864	3,365,865
2064	32	38	302,499	2,381,281	3,352,374
2065	32	38	301,286	2,371,736	3,338,937
2066	32	38	300,079	2,362,230	3,325,554
2067	31	37	298,876	2,352,761	3,312,225

a. Sources: DIRS 182251-REMI 2007, all; DIRS 179558-Bland 2007, all; DIRS 180690-Bland 2007, all; DIRS 180689-Bland 2007, all.
b. Data expressed in dollars.

Table J-10. Changes from baseline for railroad operations[a] – Mina rail alignment – Nye County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County					
2015	84	16	362,670	1,558,161	1,743,161
2016	82	13	357,388	1,439,852	1,663,601
2017	81	15	353,392	1,400,823	2,268,491
2018	79	15	349,783	1,371,434	2,413,571
2019	78	15	346,723	1,363,383	2,501,460
2020	77	16	344,483	1,369,094	2,640,551
2021	76	16	343,231	1,385,055	2,752,731
2022	76	17	342,529	1,407,564	2,844,549
2023	75	17	342,880	1,433,916	2,913,439
2024	75	18	343,582	1,464,755	2,988,932
2025	75	18	344,518	1,495,175	3,067,879
2026	75	19	346,004	1,526,904	3,147,300
2027	75	19	347,677	1,558,355	3,191,342
2028	75	19	349,549	1,593,122	3,286,948
2029	75	20	351,737	1,627,191	3,369,739
2030	75	20	354,077	1,660,369	3,432,780
2031	75	20	356,417	1,696,221	3,500,640
2032	75	20	359,108	1,733,661	3,537,189
2033	76	21	361,799	1,774,611	3,620,259
2034	76	21	365,227	1,813,415	3,616,749
2035	76	21	368,655	1,851,327	3,584,601
2036	77	21	372,446	1,895,175	3,643,101
2037	77	21	376,810	1,939,635	3,694,302
2038	78	21	381,559	1,986,575	3,741,381
2039	78	21	386,556	2,031,786	3,801,051
2040	79	22	391,669	2,078,726	3,797,541
2041	80	22	396,817	2,124,635	3,679,650
2042	81	22	402,199	2,173,969	3,717,369
2043	81	22	407,616	2,228,959	3,779,712
2044	82	22	413,279	2,287,125	3,846,681
2045	83	22	418,895	2,342,115	3,712,689
2046	84	23	424,932	2,406,132	3,783,222
2047	85	23	430,829	2,471,985	3,856,599
2048	87	23	437,217	2,546,478	3,930,921
2049	88	23	443,418	2,621,691	4,009,032
2050	89	23	449,268	2,698,074	4,089,708

Table J-10. Changes from baseline for railroad operations[a] – Mina rail alignment – Nye County (page 2 of 3).

Year	Variable				
	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (continued)					
2051	90	24	455,557	2,735,847	4,146,963
2052	91	24	461,935	2,774,148	4,205,019
2053	93	24	468,402	2,812,985	4,263,889
2054	94	25	474,959	2,852,366	4,323,582
2055	95	25	481,609	2,892,299	4,384,111
2056	97	26	488,351	2,932,790	4,445,488
2057	98	26	495,188	2,973,849	4,507,724
2058	99	26	502,121	3,015,482	4,570,831
2059	101	27	509,150	3,057,698	4,634,821
2060	102	27	516,278	3,100,505	4,699,708
2061	103	27	523,506	3,143,911	4,765,502
2062	105	28	530,835	3,187,925	4,832,218
2063	106	28	538,266	3,232,556	4,899,868
2064	108	29	545,802	3,277,811	4,968,465
2065	109	29	553,443	3,323,699	5,038,023
2066	111	29	561,191	3,370,230	5,108,554
2067	112	30	569,048	3,417,413	5,180,072
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	87	17	379,045	1,623,843	2,134,782
2016	86	19	379,022	1,590,264	2,751,255
2017	86	19	378,951	1,565,460	2,908,386
2018	85	19	379,220	1,562,652	3,009,591
2019	85	20	379,993	1,572,714	3,161,925
2020	85	20	381,467	1,594,710	3,288,051
2021	85	21	383,304	1,621,971	3,393,117
2022	85	21	386,065	1,654,731	3,476,889
2023	85	22	388,978	1,690,416	3,567,330
2024	85	22	391,938	1,727,271	3,660,228
2025	86	23	395,378	1,764,009	3,753,711
2026	86	23	398,795	1,801,449	3,812,328
2027	86	24	402,340	1,841,346	3,921,138
2028	86	24	406,130	1,882,179	4,018,716
2029	87	24	409,968	1,920,906	4,096,521
2030	87	25	413,712	1,963,026	4,178,538
2031	88	25	417,620	2,005,497	4,228,380
2032	88	25	421,493	2,052,297	4,325,607

Table J-10. Changes from baseline for railroad operations[a] – Mina rail alignment – Nye County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2033	89	25	426,009	2,097,342	4,336,605
2034	89	25	430,478	2,141,685	4,319,055
2035	90	26	435,416	2,191,293	4,391,829
2036	90	26	440,692	2,242,305	4,458,051
2037	91	26	446,378	2,296,242	4,519,593
2038	92	26	452,427	2,349,360	4,595,175
2039	93	26	458,582	2,403,414	4,606,524
2040	94	27	464,666	2,455,830	4,504,266
2041	95	27	471,065	2,515,383	4,557,267
2042	96	27	477,348	2,578,797	4,636,359
2043	97	27	484,029	2,643,615	4,718,727
2044	98	27	490,546	2,707,497	4,599,972
2045	99	28	497,426	2,779,686	4,688,658
2046	100	28	504,329	2,855,853	4,777,695
2047	101	28	511,559	2,937,285	4,870,944
2048	103	28	518,766	3,022,812	4,965,831
2049	104	29	525,564	3,110,328	5,062,941
2050	105	29	532,753	3,159,582	5,138,323
2051	107	29	540,211	3,203,815	5,210,258
2052	108	30	547,774	3,248,668	5,283,201
2053	110	30	555,443	3,294,149	5,357,164
2054	111	31	563,219	3,340,266	5,432,164
2055	113	31	571,104	3,387,029	5,508,213
2056	114	32	579,099	3,434,447	5,585,326
2057	116	32	587,207	3,482,528	5,663,520
2058	118	32	595,427	3,531,283	5,742,808
2059	119	33	603,763	3,580,720	5,823,206
2060	121	33	612,216	3,630,849	5,904,729
2061	123	34	620,787	3,681,680	5,987,394
2062	124	34	629,478	3,733,223	6,071,216
2063	126	35	638,290	3,785,487	6,156,212
2064	128	35	647,226	3,838,483	6,242,397
2065	130	36	656,287	3,892,221	6,329,789
2066	131	36	665,475	3,946,711	6,418,405
2067	19	7	97,912	535,275	1,256,385

a. Sources: DIRS 182251-REMI 2007, all; DIRS 179558-Bland 2007, all; DIRS 180690-Bland 2007, all; DIRS 180689-Bland 2007, all.
b. Data expressed in dollars.

Table J-11. Changes from baseline for railroad operations[a] – Mina rail alignment – Esmeralda County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County					
2015	37	46	333,646	3,537,174	6,485,641
2016	40	47	368,625	3,515,455	6,661,215
2017	44	47	403,848	3,518,072	6,841,384
2018	48	48	440,953	3,536,957	7,029,744
2019	51	50	477,822	3,567,475	7,222,791
2020	54	51	508,146	3,603,793	7,412,327
2021	58	52	544,785	3,649,456	7,610,042
2022	62	53	588,445	3,703,296	7,814,787
2023	66	54	633,748	3,761,814	8,020,707
2024	71	55	676,009	3,820,317	8,228,970
2025	74	56	710,077	3,876,457	8,432,552
2026	77	57	742,037	3,933,781	8,632,637
2027	79	58	772,007	3,991,131	8,836,219
2028	82	59	800,807	4,047,289	9,038,629
2029	84	59	828,436	4,101,124	9,241,057
2030	86	60	851,500	4,154,972	9,443,469
2031	88	61	873,043	4,209,969	9,651,746
2032	89	61	891,191	4,267,340	9,857,664
2033	90	62	907,464	4,324,667	10,062,427
2034	91	63	920,695	4,382,023	10,267,197
2035	92	63	930,298	4,437,045	10,470,785
2036	92	64	937,091	4,493,235	10,674,383
2037	92	64	942,596	4,550,589	10,879,159
2038	92	65	946,230	4,609,159	11,087,421
2039	92	65	950,563	4,668,872	11,294,520
2040	91	65	948,228	4,727,451	11,492,272
2041	90	66	941,446	4,786,011	11,698,200
2042	89	66	929,984	4,843,402	11,899,458
2043	87	66	914,191	4,893,709	12,098,358
2044	85	66	894,069	4,935,859	12,285,571
2045	83	66	874,061	4,983,868	12,484,484
2046	81	66	854,989	5,021,325	12,671,684
2047	79	66	837,320	5,086,893	12,870,597
2048	77	66	819,535	5,153,649	13,057,797
2049	76	66	801,631	5,222,744	13,268,410
2050	74	66	783,259	5,268,395	13,467,319

Table J-11. Changes from baseline for railroad operations[a] – Mina rail alignment – Esmeralda County (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (continued)					
2051	74	66	784,764	5,278,517	13,493,193
2052	74	66	786,272	5,288,659	13,519,117
2053	74	66	787,782	5,298,819	13,545,090
2054	74	66	789,296	5,309,000	13,571,114
2055	75	66	790,812	5,319,200	13,597,187
2056	75	66	792,332	5,329,419	13,623,311
2057	75	67	793,854	5,339,658	13,649,485
2058	75	67	795,379	5,349,917	13,675,709
2059	75	67	796,907	5,360,196	13,701,983
2060	75	67	798,438	5,370,494	13,728,308
2061	75	67	799,972	5,380,812	13,754,684
2062	76	67	801,509	5,391,150	13,781,110
2063	76	67	803,049	5,401,508	13,807,587
2064	76	67	804,592	5,411,885	13,834,115
2065	76	68	806,138	5,422,283	13,860,694
2066	76	68	807,687	5,432,700	13,887,323
2067	76	68	809,238	5,443,138	13,914,004
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	37	46	333,664	3,535,969	6,485,513
2016	40	47	368,575	3,513,757	6,661,035
2017	44	47	403,797	3,516,059	6,841,201
2018	48	48	440,893	3,534,774	7,029,571
2019	51	50	477,753	3,565,191	7,222,619
2020	54	51	508,062	3,601,469	7,412,164
2021	58	52	544,686	3,647,117	7,609,883
2022	62	53	588,330	3,700,962	7,814,628
2023	66	54	633,616	3,759,500	8,020,553
2024	71	55	675,859	3,818,040	8,228,830
2025	74	56	709,911	3,874,228	8,432,408
2026	77	57	741,857	3,931,588	8,632,489
2027	79	58	771,814	3,988,966	8,836,060
2028	82	59	800,602	4,045,152	9,038,475
2029	84	59	828,219	4,099,014	9,240,893
2030	86	60	851,273	4,152,890	9,443,310
2031	88	61	872,807	4,207,918	9,651,576
2032	89	61	890,948	4,265,301	9,857,498

Table J-11. Changes from baseline for railroad operations[a] – Mina rail alignment – Esmeralda County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2033	90	62	907,215	4,322,659	10,062,255
2034	91	63	920,441	4,380,039	10,267,018
2035	92	63	930,039	4,435,072	10,470,596
2036	92	64	936,830	4,491,278	10,674,176
2037	92	64	942,333	4,548,656	10,878,954
2038	92	65	945,964	4,607,224	11,087,212
2039	92	65	950,297	4,666,950	11,294,293
2040	91	65	947,962	4,725,511	11,492,045
2041	90	66	941,181	4,784,072	11,697,974
2042	89	66	929,719	4,841,449	11,899,223
2043	87	66	913,928	4,891,799	12,098,123
2044	85	66	893,808	4,933,958	12,285,331
2045	83	66	873,804	4,981,990	12,484,244
2046	81	66	854,737	5,019,456	12,671,444
2047	79	66	837,071	5,085,032	12,870,349
2048	77	66	819,291	5,151,797	13,057,544
2049	76	66	801,392	5,220,887	13,268,166
2050	74	66	783,024	5,266,565	13,467,070
2051	74	66	784,529	5,276,684	13,492,944
2052	74	66	786,036	5,286,822	13,518,867
2053	74	66	787,546	5,296,979	13,544,840
2054	74	66	789,059	5,307,156	13,570,864
2055	75	66	790,575	5,317,352	13,596,937
2056	75	66	792,094	5,327,568	13,623,060
2057	75	67	793,616	5,337,804	13,649,233
2058	75	67	795,141	5,348,059	13,675,457
2059	75	67	796,668	5,358,334	13,701,731
2060	75	67	798,199	5,368,629	13,728,055
2061	75	67	799,733	5,378,943	13,754,430
2062	76	67	801,269	5,389,277	13,780,856
2063	76	67	802,808	5,399,632	13,807,332
2064	76	67	804,351	5,410,006	13,833,860
2065	76	68	805,896	5,420,400	13,860,438
2066	76	68	807,445	5,430,814	13,887,067
2067	76	68	808,996	5,441,247	13,913,748

a. Sources: DIRS 182251-REMI 2007, all; DIRS 179558-Bland 2007, all; DIRS 180690-Bland 2007, all; DIRS 180689-Bland 2007, all.
b. Data expressed in dollars.

Table J-12. Changes from baseline for railroad operations[a] – Mina rail alignment – Clark County (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County					
2015	904	63	3,662,945	11,734,492	9,631,874
2016	803	21	3,286,151	9,158,889	5,096,391
2017	710	4	2,925,899	7,489,604	2,839,156
2018	627	2	2,601,864	6,524,786	2,062,276
2019	556	8	2,321,009	6,087,944	2,258,708
2020	494	17	2,075,309	5,908,934	2,811,814
2021	442	28	1,864,709	5,829,197	3,767,271
2022	397	39	1,686,761	6,034,685	4,677,098
2023	359	49	1,535,831	6,364,496	5,712,548
2024	328	58	1,408,192	6,649,976	6,569,597
2025	301	65	1,297,042	6,926,834	7,373,387
2026	277	71	1,203,333	7,185,404	7,998,167
2027	256	75	1,113,532	7,364,716	8,640,789
2028	237	78	1,041,066	7,632,214	9,033,617
2029	220	82	970,737	7,863,874	9,497,229
2030	206	83	910,541	7,997,686	9,818,687
2031	192	85	858,008	8,212,101	10,175,829
2032	181	86	814,554	8,462,481	10,550,534
2033	173	88	778,869	8,649,248	10,872,284
2034	166	88	747,618	8,908,684	11,211,279
2035	161	89	733,122	9,131,721	11,461,964
2036	159	90	719,714	9,381,236	11,764,994
2037	157	91	719,726	9,649,329	11,853,317
2038	156	91	718,544	9,864,013	12,193,214
2039	158	91	730,899	9,988,594	12,456,756
2040	161	91	746,460	10,211,631	12,673,557
2041	164	91	768,807	10,435,534	12,801,017
2042	170	91	791,154	10,622,864	13,152,614
2043	174	92	821,282	10,889,752	13,438,959
2044	181	92	847,946	11,273,512	13,795,517
2045	188	93	883,748	11,764,654	14,222,859
2046	195	95	921,609	12,279,454	14,714,856
2047	202	97	956,284	12,817,654	15,152,717
2048	209	99	990,853	13,350,308	15,784,517
2049	216	101	1,026,484	13,911,300	16,357,208
2050	222	103	1,057,831	14,567,108	17,142,314

Table J-12. Changes from baseline for railroad operations[a] – Mina rail alignment – Clark County (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (continued)					
2051	224	105	1,069,252	14,724,387	17,327,397
2052	226	106	1,080,797	14,883,364	17,514,478
2053	229	107	1,092,466	15,044,058	17,703,579
2054	231	108	1,104,261	15,206,486	17,894,722
2055	234	109	1,116,184	15,370,669	18,087,929
2056	236	110	1,128,235	15,536,623	18,283,221
2057	239	111	1,140,416	15,704,370	18,480,623
2058	242	113	1,152,729	15,873,928	18,680,155
2059	244	114	1,165,175	16,045,316	18,881,842
2060	247	115	1,177,755	16,218,555	19,085,707
2061	249	116	1,190,471	16,393,664	19,291,772
2062	252	118	1,203,325	16,570,664	19,500,063
2063	255	119	1,216,317	16,749,575	19,710,602
2064	258	120	1,229,449	16,930,418	19,923,414
2065	260	121	1,242,723	17,113,213	20,138,524
2066	263	123	1,256,141	17,297,982	20,355,957
2067	266	124	1,269,703	17,484,746	20,575,737
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	911	74	3,691,958	12,528,945	10,694,151
2016	813	32	3,326,322	10,060,479	6,194,331
2017	722	15	2,979,452	8,480,394	3,963,843
2018	642	13	2,666,582	7,533,513	3,204,864
2019	573	19	2,394,651	7,114,536	3,365,622
2020	514	28	2,156,766	6,917,625	3,945,474
2021	462	38	1,952,859	6,837,831	4,918,680
2022	419	49	1,781,606	7,061,184	5,837,130
2023	383	59	1,635,134	7,364,214	6,891,300
2024	352	68	1,513,079	7,685,496	7,747,740
2025	325	75	1,404,117	7,989,111	8,569,080
2026	303	81	1,312,740	8,274,474	9,247,680
2027	282	85	1,227,330	8,400,132	9,872,460
2028	264	88	1,155,960	8,694,504	10,300,680
2029	247	91	1,091,259	8,943,948	10,800,270
2030	233	93	1,032,174	9,077,796	11,139,570
2031	220	95	981,864	9,301,149	11,567,790
2032	210	97	938,457	9,578,322	11,997,180

Table J-12. Changes from baseline for railroad operations[a] – Mina rail alignment – Clark County (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2033	202	98	907,218	9,747,153	12,300,210
2034	195	99	879,255	10,024,443	12,747,150
2035	191	100	866,970	10,283,130	12,979,980
2036	188	101	853,632	10,497,006	13,300,560
2037	186	102	853,632	10,738,260	13,442,130
2038	186	102	856,908	11,006,190	13,906,620
2039	188	102	869,310	11,140,155	14,134,770
2040	191	102	887,094	11,389,950	14,405,040
2041	195	103	910,494	11,667,240	14,640,210
2042	200	103	934,011	11,881,350	15,045,030
2043	205	104	966,303	12,184,380	15,366,780
2044	212	104	995,202	12,576,330	15,848,820
2045	219	105	1,033,227	13,059,540	16,240,770
2046	228	107	1,071,135	13,582,530	16,857,360
2047	234	109	1,110,213	14,157,000	17,348,760
2048	242	112	1,149,291	14,743,170	18,087,030
2049	250	114	1,184,976	15,339,870	18,677,880
2050	256	117	1,220,778	15,995,070	19,641,960
2051	259	118	1,233,959	16,167,766	19,854,031
2052	262	119	1,247,281	16,342,327	20,068,392
2053	265	121	1,260,748	16,518,773	20,285,068
2054	268	122	1,274,360	16,697,124	20,504,083
2055	270	123	1,288,119	16,877,400	20,725,462
2056	273	124	1,302,027	17,059,623	20,949,232
2057	276	126	1,316,085	17,243,813	21,175,418
2058	279	127	1,330,294	17,429,992	21,404,046
2059	282	129	1,344,657	17,618,181	21,635,142
2060	285	130	1,359,175	17,808,402	21,868,733
2061	288	131	1,373,850	18,000,677	22,104,847
2062	292	133	1,388,683	18,195,027	22,343,510
2063	295	134	1,403,677	18,391,477	22,584,749
2064	298	136	1,418,832	18,590,047	22,828,594
2065	301	137	1,434,151	18,790,761	23,075,070
2066	304	139	1,449,635	18,993,642	23,324,209
2067	308	140	1,465,287	19,198,713	23,576,037

a. Sources: DIRS 182251-REMI 2007, all; DIRS 179558-Bland 2007, all; DIRS 180690-Bland 2007, all; DIRS 180689-Bland 2007, all.
b. Data expressed in dollars.

Table J-13. Changes from baseline for railroad operations[a] – Mina rail alignment – Washoe County-Carson City (page 1 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County					
2015	313	24	1,434,226	4,404,941	3,276,281
2016	273	9	1,262,376	3,446,060	1,774,516
2017	238	2	1,108,539	2,767,354	1,055,586
2018	208	2	974,079	2,374,445	848,039
2019	182	4	859,158	2,153,210	877,009
2020	160	7	760,382	2,051,420	1,102,386
2021	142	11	677,024	2,037,052	1,383,197
2022	126	15	604,484	2,044,294	1,677,605
2023	113	18	544,175	2,089,078	1,954,672
2024	101	20	490,400	2,122,684	2,178,587
2025	91	23	443,528	2,182,027	2,392,252
2026	82	24	401,453	2,200,115	2,579,979
2027	73	25	362,068	2,213,424	2,695,809
2028	66	26	325,798	2,226,619	2,771,555
2029	59	27	293,506	2,246,725	2,861,212
2030	53	27	264,977	2,275,759	2,937,262
2031	47	28	239,588	2,323,620	3,003,729
2032	43	28	217,592	2,390,310	3,074,666
2033	40	28	201,068	2,447,749	3,138,069
2034	37	29	187,730	2,526,139	3,226,989
2035	35	29	179,909	2,588,695	3,307,064
2036	34	29	174,013	2,662,405	3,342,386
2037	34	29	172,979	2,740,682	3,400,886
2038	34	29	175,687	2,823,210	3,445,124
2039	34	29	179,944	2,858,635	3,490,321
2040	36	29	187,680	2,936,916	3,565,692
2041	38	29	197,789	3,039,444	3,583,476
2042	40	29	208,880	3,144,418	3,672,981
2043	42	29	220,884	3,264,928	3,739,788
2044	44	29	235,135	3,407,450	3,838,887
2045	47	30	250,544	3,569,974	3,949,803
2046	50	31	265,567	3,768,980	4,105,881
2047	52	31	280,940	3,978,515	4,288,986
2048	55	32	296,291	4,239,729	4,499,118
2049	58	33	309,898	4,517,218	4,704,336
2050	60	34	323,610	4,762,590	4,976,010

Table J-13. Changes from baseline for railroad operations[a] – Mina rail alignment – Washoe County-Carson City (page 2 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 1: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (continued)					
2051	61	35	327,610	4,821,460	5,037,518
2052	62	35	331,660	4,881,057	5,099,785
2053	62	35	335,760	4,941,391	5,162,823
2054	63	36	339,910	5,002,470	5,226,640
2055	64	36	344,111	5,064,305	5,291,245
2056	65	37	348,365	5,126,904	5,356,649
2057	66	37	352,671	5,190,277	5,422,862
2058	66	38	357,030	5,254,433	5,489,893
2059	67	38	361,433	5,319,382	5,557,752
2060	68	39	365,911	5,385,134	5,626,451
2061	69	39	370,434	5,451,698	5,695,998
2062	70	40	375,013	5,519,086	5,766,405
2063	71	40	379,648	5,587,306	5,837,683
2064	71	41	384,341	5,656,370	5,909,841
2065	72	41	389,092	5,726,287	5,982,892
2066	73	42	393,901	5,797,069	6,056,845
2067	74	42	398,770	5,868,725	6,131,713
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County					
2015	313	24	1,433,250	4,398,246	3,231,649
2016	273	8	1,261,260	3,432,671	1,720,961
2017	238	2	1,106,586	2,753,964	995,327
2018	207	1	971,568	2,367,755	783,323
2019	182	3	856,368	2,146,516	821,223
2020	160	7	756,756	2,040,264	1,039,904
2021	141	10	672,840	2,010,276	1,311,786
2022	125	14	599,742	2,024,209	1,597,266
2023	112	17	538,875	2,077,920	1,878,804
2024	100	20	484,542	2,102,599	2,102,706
2025	90	22	437,391	2,157,480	2,307,456
2026	80	24	394,758	2,182,266	2,486,250
2027	72	25	354,816	2,213,424	2,606,544
2028	64	25	318,546	2,222,155	2,695,680
2029	58	26	286,254	2,240,035	2,771,946
2030	51	26	256,887	2,269,064	2,847,996
2031	46	27	231,498	2,319,156	2,910,006
2032	41	27	208,944	2,385,846	2,967,554

Table J-13. Changes from baseline for railroad operations[a] – Mina rail alignment – Washoe County-Carson City (page 3 of 3).

	Variable				
Year	Population	Total employment	State and local government spending[b]	Real disposable personal income[b]	Total gross regional product[b]
Scenario 2: Assuming Nevada Railroad Control Center and National Transportation Operations Center in Nye County (continued)					
2033	38	27	192,699	2,452,211	3,035,414
2034	35	28	179,361	2,530,601	3,128,796
2035	33	28	170,703	2,604,311	3,199,950
2036	32	28	164,529	2,678,021	3,244,194
2037	32	28	162,936	2,754,071	3,302,694
2038	32	28	165,087	2,841,064	3,342,474
2039	32	28	169,065	2,869,794	3,374,280
2040	34	28	176,247	2,943,611	3,436,290
2041	35	28	185,796	3,028,285	3,454,056
2042	37	28	196,326	3,131,029	3,525,644
2043	39	28	208,611	3,251,539	3,597,014
2044	42	28	222,021	3,391,830	3,687,104
2045	44	29	236,880	3,552,120	3,798,036
2046	47	29	251,064	3,751,129	3,936,314
2047	50	30	266,157	3,951,745	4,114,890
2048	52	31	280,944	4,201,795	4,302,745
2049	55	32	294,003	4,481,510	4,499,084
2050	57	33	306,873	4,717,955	4,739,454
2051	58	33	310,666	4,776,273	4,798,037
2052	58	34	314,506	4,835,311	4,857,345
2053	59	34	318,394	4,895,080	4,917,385
2054	60	34	322,330	4,955,587	4,978,168
2055	61	35	326,314	5,016,842	5,039,703
2056	61	35	330,347	5,078,854	5,101,997
2057	62	36	334,431	5,141,633	5,165,062
2058	63	36	338,565	5,205,188	5,228,907
2059	64	37	342,749	5,269,528	5,293,540
2060	65	37	346,986	5,334,664	5,358,973
2061	65	38	351,275	5,400,604	5,425,214
2062	66	38	355,617	5,467,360	5,492,274
2063	67	38	360,013	5,534,941	5,560,163
2064	68	39	364,463	5,603,358	5,628,891
2065	69	39	368,968	5,672,620	5,698,469
2066	69	40	373,529	5,742,738	5,768,907
2067	70	40	378,146	5,813,723	5,840,215

a. Source: DIRS 181590-Bland 2007, all.
b. Data expressed in dollars.

J.1.5 PUBLIC SERVICES IMPACT ANALYSIS

To estimate potential impacts to public services, DOE assessed the changes to the county or community baseline capacity (assuming no railroad). This assessment, as described in detail in Sections 4.2.9 and 4.3.9 of the Rail Alignment EIS, is a qualitative analysis. To perform the analysis, DOE identified the relevant changes that would affect public services (population changes) and characterized the magnitude of the changes as either a positive or negative impact on public services. The analysis then qualitatively described whether the burden or benefit associated with the change would degrade or supplement the delivery of public services to the county or community. Using this methodology, DOE concluded whether impacts to the various public services in counties and communities would be small, moderate, or large.

J.1.6 TRAFFIC DELAY AT RAIL-HIGHWAY GRADE CROSSINGS

DOE estimated the delay road vehicles would experience at rail-highway grade crossings. For each grade crossing analyzed, DOE calculated the time that a given crossing would be closed for each train event and estimated the average delay per vehicle on that crossing in a 24-hour period. DOE used the following steps in the delay calculation:

<u>Step 1</u>: Calculation of blocked crossing time (T)

$$T = 0.5 + \frac{L}{V \times 88}$$

T = Blocked crossing time per train event, in minutes.

0.5 = Time necessary for any warning devices (such as gates) to engage and disengage, in minutes. Not all crossings have gates, so blocked crossing times could be overestimated for such cases.

L = Train length, in feet.

V = Train speed, in miles per hour.

88 = Conversion factor from miles per hour to feet per minute.

<u>Step 2</u>: Calculation of average crossing delay per vehicle (D)

$$D = \frac{T \times \left[\frac{R_D}{(R_D - R_A)} \right]}{2}$$

D = Average crossing delay per vehicle, in minutes.

R_D = Vehicle departure rate,[a] in vehicles per hour per lane.

R_A = Vehicle arrival rate (average daily traffic divided by the number of lanes), in vehicles per hour per lane.

2 = Factor to account for the fact that vehicles do not experience delay for the entire time that crossing is blocked. Vehicles arrive, on average, at the midpoint of the train blocked crossing time.

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[a] Vehicle departure rate is a measure of the rate at which vehicles can return to free-flow speed from a state where vehicles are stopped. Vehicle departure rates depend on a number of factors such as the presence of warning signals, numbers and types of lanes, width of lanes, road grade, sight distance, curve radius, and traffic type. Because there were not enough data available to characterize each grade crossing, DOE used default values. This analysis assumes 1,800 vehicles per hour, 1,400 vehicles per hour for arterials, 900 vehicles per hour for collectors, and 700 vehicles per hour for local roads (DIRS 176524-Transportation Research Board 2001, all).

Step 3: Calculation of the number of delayed vehicles per day (N_V)

$$N_V = \frac{T}{1,440} \times N_T \times ADT$$

N_V = Number of delayed vehicles per day.

N_T = Number of daily trains.[a]

ADT = Average daily traffic, in number of vehicles per day in both directions of traffic.

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[a] If different estimates for average train daily traffic were available, the highest estimate was considered.

Step 4: Calculation of average vehicle delay in a 24-hour period (D_{24}), in seconds

$$D_{24} = \frac{N_V}{ADT} \times D$$

Step 5: Calculation of total daily delay (D_T), in minutes

J.1.7 LEVEL OF SERVICE ANALYSIS

The calculation of level of service (LOS) for baseline and adjusted scenarios is based on the methodology included in the Highway Capacity Manual for Class I two-lane highways (DIRS 176524-Transportation Research Board 2001, Chapter 20). Two-lane highways can be divided in two types: Class I, on which users expect to drive at relatively high speeds; and Class II, on which users do not expect to travel at high speeds (that is, scenic/recreational routes). This section summarizes the complete methodology.

As described in Sections 3.2.9 and 3.3.9 of the Rail Alignment EIS, roadway performance can be characterized in terms of level of service, which is a qualitative ranking of traffic conditions experienced by roadway users. There are six levels of service that can characterize the performance of roadways, with level A representing the best operating conditions (free flow), and level F the worst.

The determination of the level of service of a given roadway is based on factors that affect how users perceive the quality of service they are receiving, such as speed, travel time, freedom to maneuver, traffic interruptions, and comfort. For Class I two-lane highways, level of service is determined in relation to percent of time-spent-following (PTSF) and average travel speed. PTSF is the average percent of travel time vehicles must travel behind slower vehicles due to the inability to pass on a two-lane highway. Table J-14 lists the criteria to determine level of service. If the passenger-car equivalent flow rate is higher than the highway capacity, the facility is oversaturated and the level is F.

Table J-14. Criteria to calculate level of service in Class I two-lane highways.[a]

Level of service	Percent time-spent-following	Average travel speed (miles per hour)
A	Less than or equal to 35 percent	Greater than 55
B	Between 35 percent and 50 percent	Between 50 and 55
C	Between 50 percent and 65 percent	Between 45 and 50
D	Between 65 percent and 80 percent	Between 40 and 45
E	Greater than 80 percent	Less than or equal to 40

[a] Source: DIRS 176524-Transportation Research Board 2001, Chapter 20.

Calculation of PTSF

The PTSF is estimated based on the demand flow rate (V_p), the directional distribution of traffic, and the percentage of no-passing zones.

$$PTSF = 100 \times (1 - e^{-0\ 000879Vp}) + f_{d/np} \qquad \text{where}$$

PTSF = percent time-spent-following

V_p = demand flow rate

$f_{d/np}$ = adjustment for the combined effect of the directional distribution of traffic and of the percentage of no-passing zones on percent time-spent-following

The flow rate V_p is an adjusted measure of traffic volume (in vehicles per hour), taking into account the percentage of daily traffic that occurs during the peak 15-minute period (peak-hour factor), a grade adjustment factor, and a heavy-vehicle adjustment factor that accounts for the percentage of trucks and recreational vehicles (RVs) on the road.

$$V_p = V / (PHF \times F_G \times F_{HV}) \qquad \text{where}$$

V_p = passenger-car equivalent flow rate for peak 15-minute period (veh/h)

V = demand volume for the peak hour (veh/h)

PHF = peak-hour factor

F_G = grade adjustment factor

F_{HV} = heavy-vehicle adjustment factor

In all level of service calculations included in this analysis, the distribution of traffic within the peak hour is assumed to be uniform. Therefore, the peak-hour factor is assumed to be 1. All roadways are also assumed to be flat, so the grade adjustment factor is also 1. The heavy-vehicle adjustment factor varied by roadway segment.

Calculation of average travel speed

The average travel speed (ATS) is estimated from the free flow speed (FFS), the demand flow rate (V_p), and an adjustment factor for the percentage of no-passing zones.

$$ATS = FFS - 0.00776V_p - f_{np} \qquad \text{where}$$

ATS = average travel speed (miles per hour)

FFS = Free flow speed (miles per hour)

V_p = demand flow rate (vehicles per hour)

f_{np} = adjustment for percentage of no passing zones

J.1.8 SENSITIVITY ANALYSIS: WORKFORCE RESIDENCY OPTION

For the Draft Rail Alignment EIS, DOE based its analysis for construction and operation of facilities at or near the Yucca Mountain Repository on historical patterns of place of residence of Nevada Test Site employees. Given that pattern, 80 percent of workers at the Yucca Mountain Repository and nearby facilities would live in Clark County and 20 percent would live in Nye County. Nye County has a perspective that most workers would not wish to make the long commute from the Las Vegas area and that the residential pattern of employees would be reversed, with 80 percent of workers at the Yucca Mountain Repository and nearby facilities living in Nye County and 20 percent living in Clark County. With this perspective in mind, DOE performed a sensitivity analysis for the Draft Repository SEIS to present bounding parameters of impacts in Nye County. For the Final Rail Alignment EIS, DOE has also performed a sensitivity analysis of the impacts of this different residential pattern for construction and operation of those facilities where the historical residential pattern was applied. Those facilities would be those near the geologic repository operations area and are the Rail Equipment Maintenance Yard, the Cask Maintenance Facility, and the Nevada Railroad Control Center and National Transportation Operations Center. The modified residency assumption is that 80 percent of the workers at these facilities will reside in Nye County and 20 percent will reside in Clark County.

J.1.8.1 Modifications of Residential Assumption – Caliente Rail Alignment

DOE used the *Policy Insight* model to identify changes in economic and demographic measures for the Caliente alignment, as shown in Sections J.1.1 and J.1.2. Analyses were made for two scenarios, one with the Nevada Railroad Control Center and National Transportation Operations Center in Lincoln County (Scenario 1) and one with these facilities in Nye County (Scenario 2). The modified residency assumption was used to develop inputs into the *Policy Insight* model, and the outputs were added to the Scenario 2 outputs for Nye and Clark Counties. Because the impacts to Nye County under Scenario 2 are slightly higher, adding the outputs from the modified residency assumption to Scenario 2 would result in slightly higher impacts (than adding them to Scenario 1), consistent with the goal of presenting bounding parameters of impacts in Nye County. The year 2013 is the peak year for economic-demographic impacts for construction of the Yucca Mountain Nye County transportation facilities.

Changing the assumption of residential patterns of employees at Nye County facilities for the Caliente rail alignment would cause some changes in the economic and demographic measures for Nye and Clark Counties reported in Sections 4.2.9.2 and 4.2.9.3. Nye County measures would be higher and Clark County numbers would be reduced.

Tables J-15 and J-16 present the results for the Caliente alignment and each shows, in Column A, the changes from the baseline of economic measures under the historical pattern of 80 percent of workers at the Yucca Mountain Repository and nearby facilities residing in Clark County and 20 percent residing in Nye County. The changes shown in Column A are reported in Chapter 4. In Tables J-15 and J-16, Column B shows the differences from Column A, should 80 percent of workers at the Yucca Mountain Repository and nearby facilities reside in Nye County, and 20 percent reside in Clark County. In Tables J-15 and J-16, Column C presents the sums of Columns A and B, which are the total changes in Nye and Clark Counties under the modified residency pattern. Column C also presents the percentage change from the baseline of the total changes under the modified residency option.

Table J-15 shows the changes in Nye and Clark Counties caused by the modified residential pattern during the construction phase of the Caliente alignment.

Table J-15. Construction phase peak year changes for the modified residential pattern – Caliente rail alignment.

County (year of peak)	Column A Scenario 2 changes from the baseline (20 percent reside in Nye County)[a]	Column B Changes due to modified residential pattern (percent)[b,c]	Column C Total changes from the baseline (percent)[d]
Nye County (2013)			
Employment	182	157 (0.78)	339 (1.69)
Population	136	126 (0.22)	262 (0.45)
State and local government spending	$739,000	$530,000 (0.23)	$1,269,000 (0.54)
Real disposable personal income	$7,540,000	$10,611,000 (0.73)	$18,151,000 (1.30)
Gross regional product	$26,157,000	$7,172,000 (0.49)	$33,329,000 (2.20)
Clark County (2013)			
Employment	1,046	-161 (< 0.1)	885
Population	1,146	-53 (< 0.1)	1,093
State and local government spending	$4,538,898	-$213,000 (< 0.1)	$4,326,000 (< 0.1)
Real disposable personal income	$65,557,089	-$9,587,000 (< 0.1)	$55,970,000 (< 0.1)
Gross regional product	$93,063,087	-$13,595,000 (< 0.1)	$79,468,000 (< 0.1)

a. Source: Tables 4-101 and 4-104.
b. Source: DIRS 185436-Bland 2008, all.
c. < = less than.
d. Column A plus Column B. Percentages measured as changes from the baseline (DIRS 178610-Bland 2007, all).

Table J-16 shows the changes in Nye and Clark Counties caused by the modified residential pattern during the operations phase of the Caliente alignment.

Table J-16. Operations phase changes for the modified residential pattern – Caliente rail alignment.

County	Column A Scenario 2 changes from the baseline (20 percent reside in Nye County)[a]	Column B Changes from Scenario 2 due to modified residential pattern[b,c]	Column C Total changes from the baseline (percent)[d]
Nye County			
Employment	67	51 (0.23)	118 (0.52)
Population	194	162 (0.22)	356 (0.49)
State and local government spending	$892,979	$743,000 (0.23)	$1,636,000 (0.51)
Real disposable personal income	$4,150,809	$3,375,000 (0.19)	$7,526,000 (0.42)
Gross regional product	$10,627,461	$7,356,000 (0.36)	$17,983,000 (0.88)
Clark County			
Employment	70	-24 (< 0.1)	46 (< 0.1)
Population	368	-30 (< 0.1)	338 (< 0.1)
State and local government spending	$1,587,807	-$128,000 (< 0.1)	$1,459,000 (< 0.1)
Real disposable personal income	$8,337,771	-$2,196,000 (< 0.1)	$6,142,000 (< 0.1)
Gross regional product	$7,854,210	-$3,017,000 (< 0.1)	$4,837,000 (< 0.1)

a. Source: Tables J-3 and J-4.
b. Source: DIRS 185436-Bland, 2008, all.
c. < = less than.
d. Column A plus Column B. Percentages measured as changes from the baseline (DIRS 178610-Bland 2007, all).

The impacts in Nye County on public services and infrastructure from construction and operation of the Caliente alignment, with the modified residency option, would not be different from those discussed in Sections 4.2.9.2 and 4.2.9.3, and would be small to moderate due to already strained resources.

If 20 percent of Yucca Mountain rail line workers at southern Nye County facilities were to reside in Clark County, rather than the historical pattern of 80 percent, then for the Caliente rail alignment there would be small percentage decreases in Clark County of less than 0.1 percent of the economic and demographic measures from those discussed in Sections 4.2.9.2 and 4.2.9.3. The impacts on Clark County from construction and operations, with the modified residency option, would not be different from those discussed in Sections 4.2.9.2 and 4.2.9.3 and would be small.

J.1.8.2 Modifications of Residential Assumption – Mina Rail Alignment

DOE used the *Policy Insight* model to identify changes in economic and demographic measures for the Mina alignment, as shown in Sections J.1.3 and J.1.4. Analyses were made for two scenarios, one with the Nevada Railroad Control Center and National Transportation Operations Center in Mineral County (Scenario 1) and one with these facilities in Nye County (Scenario 2). The modified residency assumption was used to develop inputs into the *Policy Insight* model, and the outputs were added to the Scenario 2 outputs for Nye and Clark Counties. Because the impacts to Nye County under Scenario 2 are slightly higher, adding the outputs from the modified residency assumption to Scenario 2 would result in slightly higher impacts (than adding them to Scenario 1), consistent with the goal of presenting bounding parameters of impacts in Nye County. The year 2013 is the peak year for economic-demographic impacts for construction of the Yucca Mountain Nye County transportation facilities.

Changing the assumption of residential patterns of employees at Nye County facilities for the Mina rail alignment would cause some changes in the economic and demographic measures for Nye and Clark Counties discussed in Sections 4.3.9.2 and 4.3.9.3. Nye County measures would be higher and Clark County numbers would be reduced.

Tables J-17 and J-18 present the results for the Mina alignment and each shows, in Column A, the changes from the baseline of economic measures under the historical pattern of 80 percent of workers at the Yucca Mountain Repository and nearby facilities residing in Clark County and 20 percent residing in Nye County. The changes shown in Column A are reported in Chapter 4. In Tables J-17 and J-18, Column B shows the differences from Column A, should 80 percent of workers at the Yucca Mountain Repository and nearby facilities reside in Nye County, and 20 percent reside in Clark County. In Tables J-17 and J-18, Column C presents the sums of Columns A and B, which are the total changes in Nye and Clark Counties under the modified residency pattern. Column C also presents the percentage change from the baseline of the total changes under the modified residency option.

Table J-17 shows the changes in Nye and Clark Counties caused by the modified residential pattern during the construction phase of the Mina alignment.

Table J-17. Construction phase peak year changes for the modified residential pattern – Mina rail alignment.

County (year of peak)	Column A Scenario 2 changes from the baseline (20 percent reside in Nye County)[a]	Column B Changes due to modified residential pattern (percent)[b,c]	Column C Total changes from the baseline (percent)[d]
Nye County (2013)			
Employment	45	157 (0.78)	202 (1.03)
Population	89	126 (0.22)	215 (0.37)
State and local government spending	$406,000	$530,000 (0.23)	$936,000 (0.62)
Real disposable personal income	$5,335,000	$10,611,000 (0.77)	$15,946,000 (1.63)
Gross regional product	$5,100,000	$7,172,000 (0.49)	$12,272,000 (3.97)
Clark County (2013)			
Employment	769	-161 (-< 0.1)	608 (< 0.1)
Population	1,059	-53 (-< 0.1)	1,006 (< 0.1)
State and local government spending	$4,196,088	-$213,000 (-< 0.1)	$3,983,000 (< 0.1)
Real disposable personal income	$49,024,989	-$9,587,000 (-< 0.1)	$39,483,000 (< 0.1)
Gross regional product	$69,674,787	-$13,595,000 (-< 0.1)	$56,080,000 (< 0.1)

a. Source: Tables 4-245 and 4-249.
b. Source: DIRS 185436-Bland, 2008, all.
c. < = less than.
d. Column A plus Column B. Percentages measured as changes from the baseline (DIRS 178610-Bland 2007, all).

Table J-18 shows the changes in Nye and Clark Counties caused by the modified residential pattern during the operations phase of the Mina alignment.

Table J-18. Operations phase changes for the modified residential pattern – Mina rail alignment.

County	Column A Scenario 2 changes from the baseline (20 percent reside in Nye County)[a]	Column B Changes due to modified residential pattern (percent)[b,c]	Column C Total changes from the baseline (percent)[d]
Nye County			
Employment	86	51 (0.23)	74 (0.50)
Population	23	162 (0.22)	248 (0.49)
State and local government spending	$395,378	$743,000 (0.23)	$1,138,000 (0.49)
Real disposable personal income	$1,764,009	$3,375,000 (0.19)	$5,139,000 (0.45)
Gross regional product	$3,753,711	$7,356,000 (0.36)	$11,110,000 (0.81)
Clark County			
Employment	75	-24 (< 0.1)	51 (< 0.1)
Population	325	-30 (< 0.1)	295 (< 0.1)
State and local government spending	$1,404,117	-$128,000 (< 0.1)	$1,276,000 (< 0.1)
Real disposable personal income	$7,989,111	-$2,196, 000 (< 0.1)	$5,793,000 (< 0.1)
Gross regional product	$8,569,080	-$3,017,000 (< 0.1)	$5,552,000 (< 0.1)

a. Source: Tables J-10 and J-12.
b. Source: DIRS 185436-Bland, J. 2008, all.
c. < = less than.
d. Column A plus Column B. Percentages measured as changes from the baseline (DIRS 178610-Bland 2007, all).

The impacts in Nye County on public services and infrastructure from construction and operation of the Mina alignment, with the modified residency option, would not be different from those discussed in Sections 4.3.9.2 and 4.3.9.3, and would be small to moderate due to already strained resources.

If 20 percent of Yucca Mountain rail line workers at southern Nye County facilities were to reside in Clark County, rather than the historical pattern of 80 percent, then for the Mina rail alignment there would be small percentage decreases in Clark County of less than 0.1 percent of the economic and demographic measures from those discussed in Sections 4.3.9.2 and 4.3.9.3. The impacts on Clark County from construction and operations, with the modified residency option, would not be different from those discussed in Sections 4.3.9.2 and 4.3.9.3 and would be small.

J.2 Glossary

gross regional product	The dollar value of all final goods and services produced in a given year in a specific region (such as the ***region of influence***).
real disposable income	The value of total income received after taxes; it is the income available for spending or saving; also referred to as ***real disposable personal income***.
real disposable personal income	See ***real disposable income***.
region of influence	The physical area that bounds the environmental, sociologic, economic, or cultural features of interest for the purpose of analysis.

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APPENDIX K

RADIOLOGICAL HEALTH AND SAFETY

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APPENDIX K

RADIOLOGICAL HEALTH AND SAFETY

K.1 Radiation and Human Health

K.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 is transmitted as photons. Electromagnetic radiation is emitted over a range of wavelengths and energies. Humans are most commonly aware of visible light, which is part of the spectrum of electromagnetic radiation. Radiation of longer wavelengths and lower energy includes infrared radiation, which heats material when the material and the radiation interact, and radio waves. Electromagnetic radiation of shorter wavelengths and higher energy (which are more penetrating) includes ultraviolet radiation, 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.

K.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. Usually the emitted radiation is ionizing radiation. The result of the process, called radioactive ***decay***, is the transformation of an unstable atom (a ***radionuclide***) into a different atom, accompanied by the release of energy (as radiation) as the atom 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. ***Neutrons*** emitted during nuclear fission are another type of ionizing radiation. These types of ionizing radiation can have different characteristics and levels of energy and, thus, varying 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 (shield) the radiation. Alpha particles are the least penetrating and can be stopped by a thin layer of material such as a single sheet of paper. However, if radioactive atoms (called radionuclides) emit alpha particles in the body when they decay, there is a concentrated deposition of energy near the point where the radioactive decay occurs. Shielding beta particles requires thicker layers of material such as several reams of paper or several inches of wood or water. Shielding from ***gamma rays***, which are highly penetrating, requires very thick material such as several inches to several feet of heavy material (for example, concrete or lead). Deposition of the energy by gamma rays is dispersed across the body in contrast to the local energy deposition by an alpha particle. Some gamma radiation will pass through the body without interacting with it. 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. The new lighter atoms are called ***fission products***. The fission products are usually unstable and undergo radioactive decay to reach a more stable state.

Some of the heavy atoms might not fission after absorbing a subatomic particle. Rather, a new nucleus is formed that tends to be unstable (like fission products) and undergo radioactive decay.

The radioactive 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.

K.1.3 EXPOSURE TO RADIATION AND RADIATION DOSE

Radiation that originates outside of an individual's body is called 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. ***Exposure*** to direct radiation can be mitigated by placing shielding, such as lead, between the source of the radiation and the exposed individual. Internal radiation originates inside a person's body following intake of radioactive material or radionuclides through ingestion or inhalation. Once in the body, the fate of a radioactive material is determined by its chemical behavior and how it is metabolized. If the material is soluble, it might be dissolved in bodily fluids and transported to and deposited in various body organs; if it is insoluble, it might move rapidly through the gastrointestinal tract or be deposited in the lungs.

Exposure to ionizing radiation is expressed in terms of ***absorbed dose***, which is the amount of energy imparted to matter per unit mass. Often simply called ***dose***, it is a fundamental concept in measuring and quantifying the effects of exposure to radiation. The unit of absorbed dose is the ***rad***. The different types of radiation mentioned above have different effects in damaging the cells of biological systems. ***Dose equivalent*** is a concept that considers the absorbed dose and the relative effectiveness of the type of ionizing radiation in damaging biological systems, using a radiation-specific quality factor. The unit of dose equivalent is the ***rem***. In quantifying the effects of radiation on humans, other types of concepts are also used. The concept of ***effective dose equivalent*** is used to quantify effects of radionuclides in the body. It involves estimating the susceptibility of the different tissue in the body to radiation to produce a tissue-specific weighting factor. The weighting factor is based on the susceptibility of that tissue to cancer. The sum of the products of each affected tissue's estimated dose equivalent multiplied by its specific weighting factor is the effective dose equivalent. 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 time in the body. The result is called the ***committed effective dose equivalent***. The unit of effective dose equivalent is the rem. Total effective dose equivalent is the sum of the committed effective dose equivalent from radionuclides in the body plus the dose equivalent from radiation sources external to the body (also in rem). All estimates of radiation dose in the Rail Alignment EIS, unless specifically noted otherwise, are total effective dose equivalents, which are quantified in terms of rem or ***millirem*** (mrem).

More detailed information on the concepts of radiation dose and dose equivalent are in publications of the National Council on Radiation Protection and Measurements (DIRS 101857-NCRP 1993, all) and the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, all).

The factors used to convert estimates of radionuclide intake (by inhalation or ingestion) or external exposure to radionuclides (by ***groundshine*** or ***cloudshine*** [immersion]) to radiation dose are called 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). They are based on original recommendations of the International Commission on Radiological Protection (DIRS 101836-ICRP 1991, all).

The radiation dose to an individual or to a group of people can be expressed as the ***total dose*** received or as a ***dose rate***, which is dose per unit time (usually an hour or a year). ***Collective dose*** is the total dose to an exposed population. ***Person-rem*** is the unit of collective dose. Collective dose is calculated by summing the individual dose to each member of a population. For example, if 100 workers each received 0.1 rem, the collective dose would be 10 person-rem (100 people × 0.1 rem).

K.1.4 BACKGROUND RADIATION

Nationwide, on average, members of the public are exposed to approximately 360 millirem per year from natural and manmade sources (DIRS 101855-NCRP 1987, p. 53). About 60 millirem per year is from medical radiation and consumer products. About 300 millirem per year is 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 filtered through the atmosphere. With respect to exposures resulting 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 less than 0.1 percent (0.05 millirem per year) of the total dose.

K.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); they are usually assumed to be continuous over a period, even though the dose rate might vary. For a given dose of radiation, chronic radiation exposure is usually less harmful than acute exposure because the dose rate (dose per unit time, such as rem per hour) is lower, providing more opportunity for the body to repair damaged cells.

K.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 be noted at doses in the range of 25 to 50 rad. The external symptoms of radiation sickness begin to appear following acute exposures to levels of radiation 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 received. Information on the effects of acute exposures on humans was obtained from studies of the survivors of the Hiroshima and Nagasaki bombings and from studies following a multitude of acute accidental exposures.

Acute exposures have occurred following detonations of nuclear weapons, both in wartime and during weapons testing, and in other events involving testing of nuclear materials. In addition, there is a potential for acute exposures in the event of an accident at an operating nuclear electric generating station, although Nuclear Regulatory Commission regulations require that the electric utilities design their stations such that these events are extremely unlikely. Such exposures could occur only if there were a highly unlikely failure of the containment vessel surrounding the nuclear reactor and a large release of fission products from the generating station following an accident.

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 lead to acute exposures that might immediately threaten the life of the surrounding public. This is because 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) would ship the material to the proposed repository. Thus, there would not be sufficient energy generated by the fission products in the spent nuclear fuel being shipped to melt the fuel elements and vaporize fission products, as postulated for an accident at an operating nuclear electric generating station.

K.1.5.2 Chronic Exposures at Low Dose Rates

The radiation dose estimates discussed in the Rail Alignment EIS are associated with exposure to radiation at low dose rates. Such exposures can be chronic (continuous or nearly continuous), such as those to workers who are escorts. In some instances, exposures to low levels of radiation would be intermittent (for example, infrequent exposures to an individual from radiation emitted from shipping ***casks*** as they are transported). ***Cancer*** induction is the principal potential risk to human health from exposure to low levels of radiation. However, this cancer induction is a statistical process because exposure to radiation conveys only a chance of developing cancer, not a certainty. Furthermore, other causes, such as exposure to chemical agents, can induce cancer in individuals.

K.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 (referred to as ***latent cancer fatalities***) for populations and as the incremental increases in lifetime probabilities of contracting a fatal cancer for an individual. The estimates are based on the dose received and on dose-to-health-effect conversion factors recommended by the Interagency Steering Committee on Radiation Standards (DIRS 174559-Lawrence 2002, all). The Interagency Steering Committee on Radiation Standards is comprised of eight federal agencies (the Environmental Protection Agency, the Nuclear Regulatory Commission, DOE, the Department of Defense, the Department of Homeland Security, the Department of Transportation, the Occupational Safety and Health Administration, and the 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 two state observer agencies (Illinois and Pennsylvania). The Committee estimated that, for the general population and workers, a collective dose of 1 person-rem would yield 6×10^{-4} excess latent cancer fatalities.

Sometimes, calculations of the number of latent cancer fatalities associated with radiation dose do not yield whole numbers, and, especially in environmental applications, can yield numbers less than 1.0. For example, if each individual in a population of 100,000 received a total radiation dose of 0.001 rem, the collective radiation dose would be 100 person-rem and the corresponding estimated number of latent cancer fatalities would be 0.06 (100,000 people × 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 were applied 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 would have received. In a small fraction of the groups (about 6 percent), one latent cancer fatality would result; in exceptionally few groups, two or more latent cancer fatalities would occur. The average number of latent cancer fatalities over all of the groups would be 0.06. The most likely outcome for any single group is zero latent cancer fatalities.

K.1.7 COMPARISON TO 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 the dose-to-health-effect conversion factors used in the Yucca Mountain FEIS, 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 dose-to-health-effect conversion factors are similar to the lethality adjusted cancer risk coefficients published in 2008 by the International Commission on Radiological Protection in ICRP 103, 0.00041 per person-rem for workers and 0.00055 per person-rem for individuals among the general population (DIRS 182836-ICRP 2008, p. 53). The dose-to-health-effect conversion factor recommended by the Interagency Steering Committee on Radiation Standards is also similar to the dose-to-health-effect conversion factors published by the National Research Council in the *Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII Phase 2* (DIRS 181250-National Research Council 2006, p. 15), which ranged from 0.00041 to 0.00061 latent cancer fatality per person-rem for solid cancers and 0.000050 to 0.000070 latent cancer fatality per person-rem for leukemia, and the age-specific dose-to-health-effect conversion factor published by the Environmental Protection Agency, 0.000575 latent cancer fatality per person-rem (DIRS 153733-EPA 2000, Table 7.3, p. 179).

K.1.8 LINEAR NO-THRESHOLD MODEL

The premise of the Linear No-Threshold Model, as used in radiation health effects research, is that there will be some risk, even at low radiation doses. The use of the Linear No-Threshold Model was reviewed in *Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII Phase 2* (DIRS 181250-National Research Council 2006, p. 9). The BEIR VII committee examined materials that included arguments that low doses of radiation are more harmful than the Linear No-Threshold Model would suggest. The BEIR VII committee concluded that radiation health effects research, taken as a whole, does not support this view.

K.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 issue of radiation hormesis was also reviewed in *Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII Phase 2* (DIRS 181250-National Research Council 2006, pp. 9 and 10). The BEIR VII committee did not accept the hypothesis that the risks are lower than predicted by the Linear No-Threshold Model, that they are nonexistent, or that low doses of radiation might even be beneficial. The BEIR VII committee concluded that there will be some risk, even at low radiation doses.

K.1.10 OTHER RADIATION HEALTH EFFECTS

Other health effects such as nonfatal cancers and genetic effects can occur as a result of chronic exposure to radiation. These other health effects were evaluated by the International Commission on Radiological Protection and are listed in Table K-1.

The dose-to-health-effect conversion factors for cancer listed in Table K-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. Table K-1 also 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, 0.00042 per person-rem for workers and 0.00057 per person-rem for individuals among the general population, is

Table K-1. Detriment-adjusted nominal risk coefficients for cancer and genetic effects from exposure to radiation.[a]

Population	Cancer (per rem)	Heritable effects (per rem)	Total (per rem)
Whole population	5.5×10^{-4}	2×10^{-5}	5.7×10^{-4}
Adults	4.1×10^{-4}	1×10^{-5}	4.2×10^{-4}

a. Source: DIRS 182836-ICRP 2008, p. 53.

consistent with the dose-to-health-effect conversion factor recommended by the Interagency Steering Committee on Radiation Standards. While DOE recognizes the existence of health effects other than fatal cancers, the Department has chosen to quantify the impacts in the Rail Alignment EIS in terms of latent cancer fatalities, in part because these other health effects are a small portion of the total detriment from exposure to radiation.

Radiation exposure has also been demonstrated to increase the risk of other diseases, particularly cardiovascular disease, in people exposed to high therapeutic doses and also atomic bomb survivors exposed to more modest doses.

The issue of health effects other than cancer was reviewed in *Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII Phase 2* (DIRS 181250-National Research Council 2006, p. 8). The BEIR VII committee concluded that there was no direct evidence of increased risk of noncancer diseases at low doses, and data were inadequate to quantify this risk if it exists. Radiation exposure has also been shown to increase risks of some benign tumors, but the BEIR VII committee also concluded that data were inadequate to quantify this risk.

K.1.11 EXPOSURE IN UTERO

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 following a diagnostic dose of 1 to 2 rem to the embryo or fetus *in utero* (DIRS 181250-National Research Council 2006, pp. 172 and 173). In recognition of this, exposure of declared pregnant workers is specifically addressed in DOE and Nuclear Regulatory Commission radiation protection regulations (10 Code of Federal Regulations [CFR] 835.206 and 10 CFR 20.1208), which limit the exposure of the embryo/fetus to 0.5 rem from the period of conception to birth.

K.2 Transportation Methods and Data

K.2.1 TRANSPORTATION ROUTES

K.2.1.1 Distances and Population Densities

There are many possible segments that could make up the rail alignment from its junction with the Union Pacific Railroad Mainline near Caliente, Nevada, to the repository, or its junction with the Union Pacific Railroad Mainline near Hazen, Nevada, to the repository. For the radiological transportation analyses, DOE composed four specific rail alignments from the possible segments, for both the Caliente and Mina rail corridors: (1) the rail alignment with the highest exposed population, (2) the longest distance rail alignment, (3) the rail alignment with the lowest population, and (4) the shortest distance rail alignment. In addition, DOE evaluated potential radiological impacts to workers and the public at the possible locations of the Staging Yard (Caliente-Indian Cove, Caliente-Upland, Eccles-North, and Hawthorne).

The distances were determined using geographic information system data that described the rail alignment segments. The method used to estimate the population densities within 800 meters (0.5 mile) of the rail segments is described by Johnson and Michelhaugh (DIRS 181276-Johnson and Michelhaugh 2003, Section 2.5). The population densities were determined using 2000 census data for an 800-meter (0.5-mile) band on either side of the rail alignment for urban, rural, and suburban population density zones. Urban areas were defined as areas with a population density greater than 1,284 people per square kilometer (3,326 people per square mile). Rural areas were defined as areas with a population density of less than 54 people per square kilometer (139 people per square mile). Suburban areas were areas with a population density between 54 and 1,284 people per square kilometer (139 and 3,326 people per square mile). Table K-2 lists the distance and population densities for the rail alignments. There are no urban areas along the rail alignments.

For the four potential Staging Yard locations, the population densities were determined for an 800-meter (0.5-mile) area around the Staging Yard footprint. Three of the potential Staging Yard locations (Eccles-North, Caliente-Upland, and Caliente-Indian Cove) are in Lincoln County. The Staging Yard at Hawthorne would be in Mineral County. Based on 2000 census data, there would be no residents within 800 meters (0.5 mile) of the Staging Yard at Hawthorne. Table K-3 lists the population densities for the Staging Yard locations.

K.2.1.2 Population Escalation Factors

The population densities presented in Tables K-2 and K-3 are based on 2000 census data. In the radiological transportation analyses, the estimated population impacts were escalated to the year 2067 to account for potential population growth along the rail alignments and near the Staging Yard locations during operation of the proposed railroad. The population escalation factors are based on U.S. Census Bureau 2000 data and population forecasts developed using the Regional Economics Model, Inc., REMI *Policy Insight* model (DIRS 174681-REMI 2004, all), which is updated with population projections to 2024 from the Nevada State Demographer (DIRS 174313-Nevada State Demographer [n.d.], all). Table K-4 lists the escalation factors.

K.2.2 SHIPMENTS

Estimates of shipments of spent nuclear fuel and high-level radioactive waste to the repository have been developed incorporating the use of transportation, aging, and disposal (TAD) canisters and updated cask-handling assumptions at each reactor site. Table K-5 summarizes the number of rail casks that would be shipped to the repository under the Proposed Action. Using these estimates, there would be 9,495 rail casks shipped under the Proposed Action (DIRS 181377-BSC 2007, Section 7). The 9,495 rail casks would be shipped using 2,833 trains.

K.2.3 INCIDENT-FREE TRANSPORTATION

Radiation doses during normal, incident-free transportation of radioactive materials results 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 surrounding the containers. The intensity of the radiation field around the spent nuclear fuel or high-level radioactive waste shipping container was assumed to be at its regulatory maximum, 10 millirem per hour at 2 meters (6.6 feet) from the railcar that holds the shipping container [10 CFR 71.47(b)(3)]. In addition, because most spent nuclear fuel and high-level radioactive waste would be placed in canisters before being shipped, the intensity of the radiation field around an empty shipping container was assumed not to contribute to the radiation dose for workers or members of the public.

Table K-2. Distances and population densities for the Caliente and Mina rail alignments (page 1 of 2).

Rail alignment	Segment	Total population	Total distance (mi)[a]	County	Urban distance (mi)	Suburban distance (mi)	Rural distance (mi)	Urban density (people/mi^2)[b]	Suburban density (people/mi^2)	Rural density (people/mi^2)
Caliente rail alignment[c]										
Highest population	Caliente	279	334.9	Lincoln	0	2.22	92.43	0	346.16	1.66
				Nye	0	0	222.85	0	0	0.27
				Esmeralda	0	0.072	19.31	0	573.50	0.62
Shortest distance	Caliente	213	327.7	Lincoln	0	0.22	86.25	0	346.16	1.43
				Nye	0	0	239.07	0	0	0.25
				Esmeralda	0	0	2.14	0	0	0
Longest distance	Eccles	112	336.2	Lincoln	0	0	83.81	0	0	0.41
				Nye	0	0	233.03	0	0	0.26
				Esmeralda	0	0.07	19.31	0	573.50	0.62
Lowest population	Eccles	78	329.4	Lincoln	0	0	83.81	0	0	0.41
				Nye	0	0	243.50	0	0	0.25
				Esmeralda	0	0	2.14	0	0	0
Mina rail alignment[c]										
Highest population	Hazen	941	339.1	Churchill	0	0	11.57	0	0	14.92
				Lyon	0	0.55	55.36	0	315.94	11.22
				Mineral	0	0	96.19	0	0	0.99
				Esmeralda	0	0.06	82.49	0	573.50	0.15
				Nye	0	0	92.92	0	0	0.56
Shortest distance	Hazen	904	323.4	Churchill	0	0	11.00	0	0	15.69
				Lyon	0	0.55	47.23	0	315.94	12.59
				Mineral	0	0	92.72	0	0	1.26
				Esmeralda	0	0	93.86	0	0	0.075
				Nye	0	0	78.09	0	0	0.66

Table K-2. Distances and population densities along the Caliente and Mina rail alignments (page 2 of 2).

Rail alignment	Segment	Total population	Total distance (mi)[a]	County	Urban distance (mi)	Suburban distance (mi)	Rural distance (mi)	Urban density (people/mi^2)[b]	Suburban density (people/mi^2)	Rural density (people/mi^2)
Mina rail alignment[c] (continued)										
Longest distance	Hazen	901	354.1	Churchill	0	0	19.92	0	0	8.66
				Lyon	0	0.55	53.25	0	315.94	11.62
				Mineral	0	0	90.58	0	0	1.02
				Esmeralda	0	0	108.85	0	0	0.0090
				Nye	0	0	80.93	0	0	0.64
Lowest population	Hazen	878	346.9	Churchill	0	0	11.00	0	0	15.69
				Lyon	0	0.55	47.12	0	315.94	12.62
				Mineral	0	0	101.33	0	0	0.94
				Esmeralda	0	0	108.85	0	0	0.0090
				Nye	0	0	78.09	0	0	0.66

a. mi = miles; to convert miles to kilometers, multiply by 1.6093.

b. mi^2 = square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

c. There are no urban areas along the Caliente and Mina rail alignments.

Table K-3. Population densities near possible locations for the Staging Yard.

Location[a]	Population	Population density (people per square mile)[b]
Caliente-Indian Cove	8	4.04
Caliente-Upland	2	0.994
Eccles-North	2	0.607
Hawthorne	0	0

a. The Caliente and Eccles Staging Yard locations would be in Lincoln County, Nevada; the Hawthorne Staging Yard location would be in Mineral County, Nevada.

b. To convert people per square mile to people per square kilometer, multiply by 0.3861.

Table K-4. Population escalation factors.

County	2000 population	Estimated 2067 population	Escalation factor
Churchill	24,157	53,524	2.2157
Esmeralda	1,061	1,084	1.0219
Lincoln	4,165	6,944	1.6673
Lyon	35,685	172,377	4.8305
Mineral	5,071	3,715	0.7327
Nye	32,978	131,075	3.9746

Table K-5. Rail casks that would be shipped to the repository.[a]

Type	Trains	Rail casks
Pressurized-water-reactor spent nuclear fuel	1,363	4,047
Boiling-water-reactor spent nuclear fuel	929	2,759
Naval spent nuclear fuel	80	400
DOE spent nuclear fuel	74	365
High-level radioactive waste	387	1,924
Totals	2,833	9,495

a. Source: DIRS 181377-BSC 2007, Section 7.

The rail alignment would consist of a single set of tracks with multiple sidings. Rail casks would be shipped to the repository using dedicated trains. For shipments of commercial spent nuclear fuel, there would be three casks containing spent nuclear fuel per train. For shipments of DOE spent nuclear fuel and high-level radioactive waste, there would be five casks per train. In both cases, two buffer railcars, two locomotives, and one escort railcar would be present in the dedicated train. Escorts would also be present in all areas for all rail shipments.

Radiological impacts were determined for members of the public during normal, incident-free transportation of the casks. For members of the public, radiation doses were estimated for people located within 800 meters (0.5 mile) of the rail alignment. These exposures are referred to as off-link radiation doses. Once the train left the Union Pacific Railroad Mainline, there would be normally no additional stops en route to the repository, except at the Staging Yard, and the rail alignment will be constructed with the goal of transporting shipments of spent nuclear fuel and high-level radioactive waste from the Staging Yard to the repository without a stop for a crew change (DIRS 182826-Nevada Rail Partners 2007, Section 5.1). Therefore, under normal circumstances, there would be no off-link exposures of members of the public at any en route stops. Members of the public could be potentially exposed while the train was stopped at the Staging Yard.

Exposures of individuals using the rail line are referred to as on-link radiation doses. Two trains would not be able to share the single track simultaneously, and consequently, there would be no on-link radiation doses for any members of the public because no members of the public would be sharing the track with the cask trains.

Two groups of workers would be present on the train en route to the repository, engineers and conductors, referred to as rail workers and escorts. Engineers and conductors would be located in the train locomotives at least 45.7 meters (150 feet) from the closest rail cask and would be shielded from radiation exposure by the locomotives; therefore there would be no radiation doses for these workers en route to the repository. Escorts would be situated closer to the casks and would not be shielded by the locomotives; therefore radiation doses have been estimated for these workers en route to the repository.

The train would not stop en route to the repository; therefore there would be no radiation doses from any en route stops for workers. Radiation doses have been estimated for workers located at sidings who could be potentially exposed when a train with casks containing spent nuclear fuel or high-level radioactive waste passed a train carrying empty casks or other materials stopped at a siding. For the Caliente rail alignment, a single Maintenance-of-Way Facility or a separate Maintenance-of-Way Headquarters Facility and Maintenance-of-Way Trackside Facility would be constructed. For the Mina rail alignment, a single Maintenance-of-Way Facility would be constructed. Radiation doses have also been estimated for workers present at the Maintenance-of-Way Facility or Maintenance-of-Way Trackside Facility who could be potentially exposed when a train with casks containing spent nuclear fuel or high-level radioactive waste passed by the workers en route to the repository. Workers at the Staging Yard also could be potentially exposed to radiation during railcar-handling operations. Radiation doses were estimated for two groups of workers at the Staging Yard, workers directly involved in railcar handling operations (involved workers) and workers not directly involved in railcar-handling operations (noninvolved workers).

The radiological impact analysis for spent nuclear fuel and high-level radioactive waste transportation assumes that the external radiation levels emitted from each transportation cask would be at the regulatory limit of 10 millirem per hour at a distance of 2 meters (6.6 feet). This assumption would tend to overestimate the radiation dose to workers and the public, because not all casks would be loaded with spent nuclear fuel or high-level radioactive waste that has the characteristics that would result in the cask external dose rate being at the regulatory limit. In the Electric Power Research Institute (EPRI) report *Assessment of Incident Free Transport Risk for Transport of Spent Nuclear Fuel to Yucca Mountain Using RADTRAN 5.5*, EPRI noted that more than 40 percent of the spent nuclear fuel shipped is likely to have been cooled for times greater than 20 years (DIRS 185330-EPRI 2005, p. 5-2). The longer spent nuclear fuel is stored, the lower the radiation dose rate would be when the spent nuclear fuel is shipped, and cask external dose rates would be lower than the regulatory limit. Appendix J of the Yucca Mountain FEIS discussed this issue (DIRS 155970-DOE 2002, Section J.1.3.2.4). The Yucca Mountain FEIS analysis estimated that the cask dose rate would be 50 to 70 percent of the regulatory limit. Based on this analysis, DOE expects that the radiological risks to workers and the public from incident-free transportation would be 50 to 70 percent of the values estimated in this Rail Alignment EIS.

K.2.3.1 Collective Dose Estimation Methodology

Collective radiation doses were estimated based on unit risk factors. Unit risk factors provide an estimate of the radiation doses from transporting one shipment or container of radioactive material over a unit distance of travel in a given population density zone.

Unit risk factors may also provide an estimate of the radiation dose from one container or shipment being stopped at a location such as the Staging Yard, the radiation dose from one container or shipment passing a location such as the Maintenance-of-Way Facility, or the radiation dose from one container or shipment passing a train stopped at a siding. There were five types of unit risk factors used to estimate collective incident-free radiation doses:

- Unit risk factors that were used 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 that were used to estimate incident-free radiation doses that depended on the number of casks and the distance in each population zone.
- Unit risk factors that were used to estimate incident-free radiation doses that depended on the number of casks and the population density around locations such as the Staging Yard.
- Unit risk factors that were used to estimate incident-free radiation doses that depended on the number of trains (shipments) and the distance in each population zone.
- Unit risk factors that were used to estimate incident-free radiation doses that depended on the number of casks.

The unit risk factors were combined with the cask, shipment, population density, and distance data using the following equations:

$$\text{Incident-Free Dose} = \sum_{m} \sum_{k} \sum_{j} \sum_{i} C_k \times PD_{j,m} \times D_{j,m} \times EF_m \times URF_{i,j}$$

$$\text{Incident-Free Dose} = \sum_{m} \sum_{k} \sum_{j} \sum_{i} C_k \times D_{j,m} \times URF_{i,j}$$

$$\text{Incident-Free Dose} = \sum_{m} \sum_{k} \sum_{j} \sum_{i} C_k \times PD_m \times EF_m \times URF_{i,j}$$

$$\text{Incident-Free Dose} = \sum_{m} \sum_{k} \sum_{j} \sum_{i} T_k \times D_{j,m} \times URF_{i,j}$$

$$\text{Incident-Free Dose} = \sum_{k} \sum_{j} \sum_{i} C_k \times URF_{i,j}$$

Where:

C_k = Number of casks for fuel type k

T_k = Number of trains (shipments) for fuel type k

$PD_{j,m}$ = Population density in population zone j in county m (people per square kilometer)

PD_m = Population density at Staging Yard in county m (people per square kilometer)

$D_{j,m}$ = Distance in population zone j in county m (kilometers)

EF_m = Population escalation factor for county m

$URF_{i,j}$ = Unit risk factor for receptor i in population zone j (person-rem per kilometer per people per square kilometer, person-rem per kilometer, person-rem per person per square kilometer, or person-rem)

The unit risk factors used to estimate radiation doses were estimated using the RADTRAN 5 computer code (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all; DIRS 155970, DOE 2002, p. J-40) and the RISKIND computer code (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 the Rail Alignment EIS are based on *Transportation Health and Safety Calculation/Analysis Documentation in Support of the Final EIS for Yucca Mountain Repository* (DIRS 157144-Jason Technologies 2001, Tables 4-20 and 4-21) and the following additional assumptions:

- There would be no on-link radiation doses for members of the public, as no members of the public would share the single track with the cask trains.
- There would be no radiation doses at stops for members of the public, workers, or escorts.
- There would be no radiation doses for rail workers (engineers or conductors) en route to the repository. There would, however, be radiation doses for escorts en route to the repository.
- Escorts would be present on the trains in all areas en route to the repository and would also be present at the Staging Yard.
- 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.
- Unit risk factors were estimated for workers located at the Maintenance-of-Way Facility and Maintenance-of-Way Trackside Facility, workers located at sidings, and noninvolved workers at the Staging Yard.

At the Staging Yard, there would be three groups of involved workers: inspectors, escorts, and rail workers. For the purposes of this analysis, inspectors would be present for 1 hour at a distance of 1 meter (3.3 feet) from the railcar containing the rail cask (DIRS 157144-Jason Technologies 2001, p. 88). Escorts would be present at a distance of 30 meters (100 feet) from the rail cask for a period of 2 hours. Radiation doses to rail workers were estimated using the time- and distance-weighted “b” factors contained in RADTRAN5 Technical Manual (DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, Appendix B). For noninvolved workers at the Caliente Staging Yard, 65 workers would be present 100 meters (330 feet) from the rail casks for 2 hours. At the Mina Staging Yard, 55 workers would be present 100 meters from the rail casks for 2 hours.

At the Caliente Maintenance-of-Way Facility or Maintenance-of-Way Trackside Facility, up to 50 workers would be present at the facility 60 meters (200 feet) from the railroad tracks. At the Mina Maintenance-of-Way Facility, 40 workers would be present at the facility 60 meters (200 feet) from the railroad tracks. At sidings, up to 10 workers (an engineer, a conductor, and escorts) would be present 7.62 meters (25 feet) from the railroad tracks. Workers would not be continuously present at sidings. Under the Proposed Action, a loaded cask train could pass an empty cask train or a train containing other materials at a siding up to 53 times for the Caliente rail alignment or 29 times for the Mina rail alignment. Under the Shared-Use Option, a loaded cask train could pass an empty cask train or a train containing other materials at a siding up to 114 times for the Caliente rail alignment or 62 times for the Mina rail alignment. For the Maintenance-of-Way Facilities or Trackside Facilities and passes at sidings, the train containing loaded spent nuclear fuel or high-level radioactive waste would pass the facility or siding at about 50 kilometers (30 miles) per hour.

Table K-6 contains the unit risk factors for workers and members of the public used in this analysis. Because multiple casks would be shipped in the same train, some unit risk factors depend on the number of casks, while other unit risk factors depend on the number of trains. This is noted in Table K-6.

Table K-6. Incident-free unit risk factors.

Receptor	Type of zone or person	Unit risk factor[a]	Unit risk factor[b]
Public			
Off-link (public along rail alignment)	Rural	5.01×10^{-8}	5.08×10^{-8}
(person-rem/km per people per square kilometer)[c]	Suburban	6.24×10^{-8}	6.33×10^{-8}
(based on number of casks)	Urban	1.04×10^{-7}	1.05×10^{-7}
On-link (public sharing rail alignment)	Rural	0	0
(person-rem per kilometer)[d]	Suburban	0	0
(based on number of casks)	Urban	0	0
Residents near stops en route to the repository	Rural	0	0
(person-rem per kilometer)	Suburban	0	0
(based on number of casks)	Urban	0	0
Residents located near Staging Yard	Site-specific	1.06×10^{-6}	1.08×10^{-6}
(person-rem/km per people per square kilometer)			
(based on number of casks)			
Workers			
En route rail workers (engineers and conductors)	Rural	0	0
(person-rem per kilometer)	Suburban	0	0
(based on number of trains)	Urban	0	0
En route rail workers at stops	Rural	0	0
(person-rem per kilometer)	Suburban	0	0
(based on number of casks)	Urban	0	0
En route escorts	Rural	2.08×10^{-4}	2.08×10^{-4}
(person-rem per kilometer)	Suburban	2.59×10^{-4}	2.59×10^{-4}
(based on number of trains)	Urban	4.32×10^{-4}	4.32×10^{-4}
En route escorts at stops	Rural	0	0
(person-rem per kilometer)	Suburban	0	0
(based on number of casks)	Urban	0	0
Workers at Maintenance-of-Way Facility or Trackside Facility	Caliente	4.65×10^{-6}	4.85×10^{-6}
	Mina	3.72×10^{-6}	3.88×10^{-6}
(person-rem per pass) (based on number of casks)			
Workers at siding	Rural	4.50×10^{-5}	4.50×10^{-5}
(person-rem per pass) (based on number of casks)			
Workers at Staging Yard (involved)	Escorts	2.08×10^{-2}	2.08×10^{-2}
(person-rem/train or cask)	Inspector	1.70×10^{-2}	1.70×10^{-2}
(escort based on number of trains, inspector and railyard workers based on number of casks)	Railyard workers	1.60×10^{-3}	1.68×10^{-3}
Workers at Staging Yard (noninvolved)	Caliente	1.30×10^{-3}	1.37×10^{-3}
(person-rem/cask) (based on number of casks)	Mina	1.10×10^{-3}	1.16×10^{-3}

a. Unit risk factors for shipments of commercial and DOE spent nuclear fuel and high-level radioactive waste.

b. Unit risk factors for shipments of naval spent nuclear fuel.

c. km = kilometer; to convert person-rem per kilometer per people per square kilometer to person-rem per mile per people per square mile, multiply by 0.62137.

d. To convert person-rem per kilometer to person-rem per mile, multiply by 1.6093.

K.2.3.2 Maximally Exposed Individual Scenarios

Maximally exposed individuals are hypothetical workers and members of the public who would receive the highest radiation doses. Radiation doses for these hypothetical individuals were estimated for cask shipments en route to the repository and for railcar-handling activities at the potential Staging Yard locations.

The scenarios used to estimate the radiation doses are based on the scenarios analyzed in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Section J.1.3.2.2) and the following additional assumptions. For workers, radiation doses were estimated for inspectors, escorts, and Staging Yard workers, including involved workers and noninvolved workers, under several operating scenarios. In the first scenario, a worker located at the Maintenance-of-Way Facility or Trackside Facility is exposed to a loaded cask train as it passed the facility en route to the repository. In the second scenario, a worker located at a siding is exposed to a loaded cask as it passed the siding en route to the repository. The assumptions used to evaluate these scenarios are listed in the previous section.

For members of the public, two scenarios were evaluated. In the first scenario, a resident living 18 meters (60 feet) from the rail line is exposed to all loaded casks as they passed by en route to the repository. The passing train is traveling at a speed of 24.2 kilometers (15 miles) per hour. In the second scenario, a resident living near the Staging Yard is exposed to all loaded casks at the Staging Yard for a duration of 2 hours per cask. The distances from the Staging Yard for these residents are listed in Table K-7 and were based on site-specific data around each potential Staging Yard location.

Table K-7. Distance to members of the public around potential Staging Yard locations.

Staging Yard location	Distance (feet)[a]	Type of location
Caliente-Indian Cove	5,250	Residence
Caliente-Upland	1,310	Residence
Eccles	4,920	Residence
Hawthorne	2,170	Business

a. To convert feet to meters, multiply by 0.3048.

K.2.4 TRANSPORTATION ACCIDENT RISKS

The radiological dose risks from transporting spent nuclear fuel and high-level radioactive waste could result from: 1) accidents in which there is no breach of the containment provided by the transportation cask, but there is 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 release and disperse radioactive material from the transportation cask. In the Rail Alignment EIS, 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.

As an example, the dose risk from a single accident that had a probability of 0.001 (1 chance in 1,000), and would cause a population dose of 20,000 person-rem in a population if it did occur, would be 20 person-rem. If that population was subject to 1,000 similar accident scenarios, the total dose risk would be 20,000 person-rem. Using the conversion factor of 0.0006 latent cancer fatality per person-rem, an analysis would estimate a health and safety risk of 12 latent cancer fatalities from this population dose risk.

Potential accidents ranged from accidents with high probabilities and low consequences to accidents with low probabilities and high consequences. The analyses used the following information to determine the risks of accidents:

- The number of shipments
- The distances and population densities along the rail alignments in rural, suburban, and urban areas
- The kind and amount of radioactive material that would be transported
- Track-class-specific 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
- Exposure scenarios including inhalation, ingestion, groundshine, resuspension, and immersion pathways, Nevada-specific agricultural factors, and neutral atmospheric dispersion factors

Conditional probability is the probability of an accident of a given severity category, given that an accident occurs.

As in the incident-free transportation analysis, the RADTRAN 5 computer code (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all; DIRS 155970-DOE 2002, Section J.1.4.2) was used to estimate unit risk factors 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 transporting 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. For accidents involving loss of shielding, the unit risk factors were also estimated using RADTRAN 5. The methods and data used to estimate the dose risks are based on the following:

Release fraction is the fraction of material released during an accident.

- The distances and population densities reflect specific rail alignments. This is discussed in Section K.2.1.1.
- The number of rail casks to be shipped has been estimated to be 9,495. This is discussed in Section K.2.2.
- Track Class-specific rail accident rates were used in the analysis. This is discussed in Section K.2.4.1.
- The radionuclide inventories are as discussed in Section K.2.4.2.
- Radiation dosimetry has been used to estimate unit risk factors and radiation doses. This is discussed in Section K.2.4.7.
- Health risk conversion factors have been used to estimate the number of latent cancer fatalities. This is discussed in Section K.1.6.

Transportation accidents are organized into categories based on the severity of the accident. These categories are known as severity categories.

For the inhalation, immersion, resuspension, and groundshine pathways, the dose risk is given by:

$$\text{Dose Risk} = \text{AR} \times \sum_{p} \sum_{n} \sum_{m} \sum_{j} \sum_{i} \sum_{k} \text{PD}_{m,p} \times \text{D}_{m,p} \times \text{I}_{i,n} \times \text{CP}_{j,n} \times \text{RF}_{i,j,n} \times \text{EF}_{p} \times \text{URF}_{i,k}$$

Where:

AR = Accident rate (accidents/kilometer)

$\text{PD}_{m,p}$ = Population density in population zone m in county p (people/square kilometer)

$\text{D}_{m,p}$ = Distance in population zone m in county p (kilometer)

$\text{I}_{i,n}$ = Total inventory of radionuclide i for fuel type n (Ci)

$\text{CP}_{j,n}$ = Conditional probability for severity category j and fuel type n

$\text{RF}_{i,j,n}$ = Release fraction for radionuclide i and severity category j for fuel type n

EF_{p} = Population escalation factor for county p

$\text{URF}_{i,k}$ = Unit risk factor for radionuclide i and pathway k (person-rem/Ci per person/square kilometer)

For the ingestion pathway, the dose risk is given by:

$$\text{Dose Risk} = \text{AR} \times \sum_{p} \sum_{n} \sum_{j} \sum_{i} \text{D}_{rural,p} \times \text{I}_{i,n} \times \text{CP}_{j,n} \times \text{RF}_{i,j,n} \times \text{FTF}_{i} \times \text{URF}_{i}$$

Where:

AR = Accident rate (accidents/kilometer)

$\text{D}_{rural,p}$ = Distance in rural population zone in county p (kilometer)

$\text{I}_{i,n}$ = Total inventory of radionuclide i for fuel type n (Ci)

$\text{CP}_{j,n}$ = Conditional probability for severity category j and fuel type n

$\text{RF}_{i,j,n}$ = Release fraction for radionuclide i and severity category j and fuel type n

FTF_{i} = Food transfer factor for radionuclide i (Ci/Ci deposited) (state-specific)

URF_{i} = Ingestion unit risk factor for radionuclide i (person-rem/Ci × Ci deposited)

For loss of shielding accidents, the dose risk is given by:

$$\text{Dose Risk} = \text{AR} \times \sum_{p} \sum_{n} \sum_{m} \sum_{j} \text{C}_{n} \times \text{PD}_{m,p} \times \text{D}_{m,p} \times \text{CP}_{j,n} \times \text{EF}_{p} \times \text{URF}_{j,n}$$

Where:

AR = Accident rate (accidents/kilometer)

C_{n} = Number of casks for fuel type n

$\text{PD}_{m,p}$ = Population density in population zone m in county p (people/square kilometer)

$D_{m,p}$ = Distance in population zone m in county p (kilometer)

$CP_{j,n}$ = Conditional probability for severity category j and fuel type n

EF_p = Population escalation factor for county p

$URF_{j,n}$ = Loss of shielding unit risk factor for severity category j and fuel type n (person-rem per person/square kilometer)

K.2.4.1 Transportation Accident Rates

In this analysis, the Department used a combination of rail accident rates based on both train-miles and railcar-miles to estimate accident dose risks (see Table K-8). These rates were for Track Class 3 and include derailments and collisions (DIRS 180220-Bendixen and Facanha 2007, all).

Table K-8. Track Class 3 rail accident rates.[a]

Train-based accident rate (accidents per train-mile)[b]	Railcar-based accident rate (accidents per railcar-mile)[c]
1.2×10^{-6}	2.7×10^{-8}

a. Source: DIRS 180220-Bendixen and Facanha 2007, p. 2.
b. To convert accidents per train-mile to accidents per train-kilometer, multiply by 0.62137.
c. To convert accidents per railcar-mile to accidents per railcar-kilometer, multiply by 0.62137.

K.2.4.2 Radionuclide Inventory

The primary sources of the radionuclide inventory information for the Rail Alignment EIS 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)
- *Recommended Values for HLW Glass for Consistent Usage on the Yucca Mountain Project* (DIRS 184907-BSC 2008, all)

Quantities of spent nuclear fuel are traditionally expressed in terms of metric tons of heavy metal (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 material. A metric ton is 1,000 kilograms (1.1 short tons or 2,200 pounds). The radionuclide inventory used in the Rail Alignment EIS represents the radioactivity contained in about 65,600 MTHM of spent nuclear fuel and high-level radioactive waste that would be shipped to the repository by rail. The remaining 4,400 MTHM would be shipped to the repository using trucks and is not evaluated in the Rail Alignment EIS. The updated radionuclide inventories are listed in Tables K-9 through K-14.

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***, affect the radionuclide inventory and thereby the radiation dose. The descriptions below are for a typical spent nuclear fuel for each group.

- 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 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 to 93.2 percent. The cladding is in good to fair condition. This group of fuel comprises approximately 0.19 MTHM.

Enrichment is the fraction of atoms of a specified isotope in a mixture of isotopes of the same element when this fraction exceeds that in the naturally occurring mixture. By convention, uranium enrichment is given on a weight basis.

Decay time is the time since the spent nuclear fuel has been discharged from the reactor.

Burnup is the total energy released per initial unit mass of nuclear fuel as a result of irradiation. The commonly used units of burnup are megawatt-days per metric ton of heavy metal (MWd/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 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, Nonintact 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 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, Nonintact 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, Nonintact 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 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 to 20 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 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- or BISO-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 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 to 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 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 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 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 will be 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 percent. If present, the cladding is in good to poor condition. This group of fuel comprises approximately 0.44 MTHM.

For DOE spent nuclear fuel, 752 canisters from the Hanford Site, 1,603 canisters from the Idaho National Laboratory, 400 canisters from the Savannah River Site, and 400 canisters of naval spent nuclear fuel would be shipped (DIRS 181377-BSC 2007, Section 7). The DOE spent nuclear fuel radionuclide inventories are for the amount of spent nuclear fuel that would be shipped in rail casks. The radionuclide inventories for DOE spent nuclear fuel were compiled from data contained in *Source Term Estimates for DOE Spent Nuclear Fuels* (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 information provided by the Department of the Navy (DIRS 155857-McKenzie 2001, Table 3). Tables K-9 through K-12 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 would be shipped in rail casks. For pressurized-water-reactor spent nuclear fuel, 85,914 spent nuclear fuel assemblies are estimated to be shipped in rail casks (DIRS 181377-BSC 2007, Section 7). For boiling-water-reactor spent nuclear fuel, 121,932 spent nuclear fuel assemblies are estimated to be shipped in rail casks (DIRS 181377-BSC 2007, Section 7). For the purposes of analysis, all shipping casks were assumed to be full and all trains were assumed to have a full complement of casks. This increases the number of spent nuclear fuel assemblies to 87,057 for pressurized-water-reactor spent nuclear fuel and 123,537 for boiling-water-reactor spent nuclear fuel. The representative pressurized-water-reactor assembly would have a burnup of 60,000 megawatt-days per metric ton of heavy metal (MWd/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 MWd/MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 164364-BSC 2003, all). Table K-13 contains the radionuclide inventory for commercial spent nuclear fuel.

The high-level radioactive waste radionuclide inventory is based on 5,316 canisters for Hanford Site high-level radioactive waste, 528 canisters for Idaho National Laboratory high-level radioactive waste, 3,490 canisters of Savannah River Site high-level radioactive waste, and 277 canisters of high-level radioactive waste from West Valley (DIRS 181377-BSC 2007, Section 7). This radionuclide inventory is based on the recommended values from *Recommended Values for HLW Glass for Consistent Usage on the Yucca Mountain Project* (DIRS 184907-BSC 2008, Tables 3, 8, 15, and 17) and represents the average radionuclide inventory in a canister at the Hanford Site, the Idaho National Laboratory, and West Valley.

For the Savannah River Site, the radionuclide inventory represents the maximum radiological loading for future production (DIRS 184907-BSC 2008, p. 15). For the purposes of analysis, all shipping casks containing high-level radioactive waste were assumed to be full and all trains were assumed to have a full complement of casks. This increases the amount of high-level radioactive waste to 5,325 canisters for Hanford Site high-level radioactive waste, 550 canisters for Idaho National Laboratory high-level radioactive waste, 3,500 canisters of Savannah River Site high-level radioactive waste, and 300 canisters of high-level radioactive waste from West Valley and also increases the total radionuclide inventory to that which would be present in these numbers of canisters. Table K-14 lists the radionuclide inventory for high-level radioactive waste.

Table K-9. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 1 through 8[a,b] (page 1 of 2).

	Uranium metal				Uranium oxide			
					Zirconium clad (intact)			Stainless steel/hastelloy clad (intact)
Radionuclide	Zirconium clad LEU Group 1 (Ci)	Non-zirconium clad LEU Group 2 (Ci)	Uranium-zirconium Group 3 (Ci)	Uranium-molybdenum Group 4 (Ci)	HEU Group 5 (Ci)	MEU Group 6 (Ci)	LEU Group 7 (Ci)	HEU Group 8 (Ci)
Ac-227	5.0E-3	5.8E-4	3.0E-3	8.4E-3	5.4E-3	2.9E-5	4.2E-3	1.0E-4
Am-241	7.1E+5	2.1E+4	1.4E+4	1.8E+2	4.6E+2	4.8E+3	3.7E+5	4.6E-1
Am-242m	4.4E+2	3.4E+1	2.2E+0	2.8E-2	8.6E-1	9.7E+0	7.8E+2	3.5E-5
Am-243	3.7E+2	6.4E+0	1.3E+0	1.6E-2	1.8E+0	2.1E+1	1.7E+3	4.1E-6
C-14	1.1E+3	2.0E+3	7.0E+2	1.1E+1	5.3E+1	1.6E+0	6.6E+2	9.5E-1
Cl-36	5.2E-2	3.7E+1	1.2E-3	4.8E-3	2.8E-1	2.7E-2	2.1E+0	5.1E-3
Cm-243	1.7E+1	6.6E+0	3.1E-1	4.0E-3	7.5E-1	8.7E+0	7.6E+2	9.8E-7
Cm-244	6.5E+3	8.9E+1	6.5E+0	8.3E-2	1.5E+2	1.7E+3	1.6E+5	8.9E-6
Co-60	2.7E+4	4.6E+5	4.0E+4	6.8E+2	1.6E+4	1.2E+2	4.7E+4	2.5E+2
Cs-134	1.1E+2	1.5E+2	5.0E+0	1.2E-1	1.8E+0	1.9E+1	2.6E+3	1.0E-2
Cs-135	7.6E+1	1.9E+0	5.0E+0	4.0E+0	7.0E+0	4.9E-1	4.2E+1	1.3E-1
Cs-137	9.3E+6	2.2E+5	9.0E+5	1.3E+5	3.4E+5	4.8E+4	4.9E+6	5.7E+3
Eu-154	5.2E+4	1.2E+3	4.2E+3	6.9E+1	2.3E+2	7.8E+2	9.1E+4	2.4E+0
Eu-155	2.5E+3	7.7E+2	3.9E+2	1.3E+2	1.7E+2	8.5E+1	1.2E+4	2.5E+0
Fe-55	4.7E+1	6.2E+3	3.7E+1	1.7E+0	2.8E+2	6.8E+0	1.1E+3	4.2E+0
H-3	2.6E+4	4.2E+3	1.5E+4	4.9E+2	6.5E+2	7.6E+2	8.7E+4	9.4E+0
I-129	6.5E+0	1.3E-1	4.7E-1	1.1E-1	1.7E-1	3.3E-2	2.9E+0	3.0E-3
Kr-85	2.1E+5	7.5E+3	2.4E+4	3.7E+3	9.6E+3	1.0E+3	1.3E+5	1.5E+2
Np-237	6.4E+1	1.9E+0	3.5E+0	3.3E-1	3.0E-1	3.8E-1	3.1E+1	4.8E-3
Pa-231	1.2E-2	1.1E-3	5.0E-3	1.7E-2	1.0E-2	4.3E-5	6.9E-3	2.0E-4
Pb-210	2.0E-3	3.6E-4	2.7E-3	3.5E-5	3.7E-7	2.7E-6	2.2E-3	3.1E-9
Pm-147	4.7E+3	1.6E+4	6.2E+2	1.1E+2	2.8E+2	5.6E+1	8.9E+3	4.0E+0
Pu-238	1.5E+5	3.6E+3	4.0E+3	6.5E+1	2.9E+2	2.5E+3	2.1E+5	1.2E+0
Pu-239	2.2E+5	7.1E+3	1.2E+4	1.8E+3	2.0E+2	3.9E+2	4.0E+4	2.8E+0

Table K-9. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 1 through 8[a,b] (page 2 of 2).

	Uranium metal				Uranium oxide			
					Zirconium clad (intact)			Stainless steel/hastelloy clad (intact)
Radionuclide	Zirconium clad LEU Group 1 (Ci)	Non-zirconium clad LEU Group 2 (Ci)	Uranium-zirconium Group 3 (Ci)	Uranium-molybdenum Group 4 (Ci)	HEU Group 5 (Ci)	MEU Group 6 (Ci)	LEU Group 7 (Ci)	HEU Group 8 (Ci)
Pu-240	1.7E+5	3.5E+3	5.2E+3	7.1E+1	7.3E+1	5.1E+2	4.4E+4	3.6E-1
Pu-241	4.5E+6	1.4E+5	9.1E+4	1.1E+3	3.5E+3	3.2E+4	3.2E+6	2.7E+0
Pu-242	1.1E+2	1.9E+0	1.3E+0	1.6E-2	1.9E-1	2.2E+0	1.7E+2	8.2E-6
Ra-226	5.6E-3	9.7E-4	7.4E-3	9.4E-5	1.0E-6	7.3E-6	6.0E-3	8.2E-9
Ra-228	4.9E-4	2.4E-5	7.4E-4	1.1E-5	1.9E-6	1.8E-7	5.7E-4	3.4E-8
Ru-106	4.4E-3	1.1E+3	2.1E-4	2.9E-5	2.1E-3	2.6E-1	5.1E+2	6.3E-7
Se-79	8.4E+1	3.1E+0	7.8E+0	1.5E+0	3.1E+0	4.2E-1	3.9E+1	5.5E-2
Sn-126	6.6E+0	2.5E+0	7.5E+0	3.4E+0	2.7E+0	8.5E-1	7.2E+1	4.8E-2
Sr-90	6.7E+6	1.6E+5	7.9E+5	1.1E+5	3.2E+5	3.2E+4	3.4E+6	5.4E+3
Tc-99	2.8E+3	5.9E+1	2.8E+2	4.2E+1	1.1E+2	1.3E+1	1.2E+3	1.9E+0
Th-229	1.8E-3	1.8E-4	2.7E-3	3.8E-5	3.7E-6	4.0E-6	2.3E-3	6.4E-8
Th-230	5.6E-1	8.8E-2	6.7E-1	8.6E-3	9.6E-5	6.9E-4	5.5E-1	7.3E-7
Th-232	4.9E-4	2.4E-5	7.5E-4	1.1E-5	1.9E-6	1.8E-7	5.8E-4	3.5E-8
Tl-208	3.0E-2	2.0E-2	2.9E-2	8.7E-4	5.5E-3	6.0E-3	5.1E-1	8.8E-5
U-232	8.2E-2	5.4E-2	7.8E-2	2.3E-3	1.5E-2	1.6E-2	1.4E+0	2.4E-4
U-233	3.9E-1	3.9E-2	5.7E-1	8.0E-3	8.0E-4	8.5E-4	5.0E-1	1.3E-5
U-234	1.4E+3	1.9E+2	1.5E+3	1.9E+1	2.6E-1	1.7E+0	1.2E+3	1.6E-3
U-235	4.8E+1	8.2E-2	6.0E-3	2.0E+0	9.9E-1	2.0E-1	2.3E+0	3.9E-1
U-236	9.7E+1	2.8E+0	1.7E+1	1.3E+0	3.7E+0	2.6E-1	3.3E+1	6.7E-2
U-238	7.0E+2	2.1E+0	3.3E-1	1.0E+0	2.1E-2	6.0E-1	3.0E+1	4.7E-3

a. LEU = low-enriched uranium; MEU = medium-enriched uranium; HEU = high-enriched uranium.

b. Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.

Table K-10. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 9 through 16[a,b] (page 1 of 2).

	Uranium oxide							
	Stainless steel clad (intact)		Not aluminum clad nonintact or declad			Aluminum clad		Uranium-aluminum
Radionuclide	MEU Group 9 (Ci)	LEU Group 10 (Ci)	HEU Group 11 (Ci)	MEU Group 12 (Ci)	LEU Group 13 (Ci)	HEU Group 14 (Ci)	MEU and LEU Group 15 (Ci)	HEU Group 16 (Ci)
Ac-227	1.4E-4	9.5E-4	5.6E-3	8.5E-4	4.2E-3	8.8E-4	1.3E-5	1.0E-3
Am-241	1.1E+0	1.8E+4	1.9E+4	1.5E+3	4.7E+4	4.9E+3	4.8E+1	5.2E+3
Am-242m	1.1E-4	8.8E+0	3.8E+1	3.0E+0	1.1E+2	9.9E-1	1.6E-2	1.6E+0
Am-243	1.2E-5	4.5E+0	3.7E+1	6.5E+0	2.3E+2	1.5E+1	5.4E-2	1.8E+1
C-14	2.7E+0	1.9E+3	2.8E+2	1.5E+1	8.5E+1	1.6E-2	2.1E-4	3.0E-1
Cl-36	1.5E-2	3.6E+1	5.2E+0	8.4E-2	6.5E-1	1.7E-25	4.7E-28	2.7E-4
Cm-243	4.2E-6	1.4E+0	2.0E+0	2.7E+0	1.1E+2	2.5E+0	7.9E-3	3.7E+0
Cm-244	4.9E-5	6.3E+1	3.9E+2	5.3E+2	2.6E+4	2.1E+3	1.7E+0	3.3E+3
Co-60	1.1E+4	4.4E+5	1.0E+5	1.6E+4	8.1E+4	5.1E+1	1.1E+0	3.6E+2
Cs-134	1.7E+2	5.2E+0	6.8E+2	7.1E+0	4.4E+2	7.4E+4	1.3E+4	1.3E+6
Cs-135	3.6E-1	1.1E+0	1.8E+0	2.0E+0	1.4E+1	5.5E+0	1.2E-1	9.7E+0
Cs-137	2.4E+4	1.6E+5	1.0E+5	1.3E+5	1.2E+6	3.2E+6	9.6E+4	6.9E+6
Eu-154	3.2E+1	8.1E+2	3.0E+3	3.3E+2	1.7E+4	5.9E+4	2.5E+3	2.1E+5
Eu-155	1.3E+2	2.4E+2	6.1E+2	2.0E+2	3.4E+3	2.0E+4	1.1E+3	1.1E+5
Fe-55	8.5E+3	4.6E+3	3.5E+4	1.1E+3	5.4E+3	4.6E+3	1.9E+2	3.7E+4
H-3	7.3E+1	3.9E+3	7.3E+2	5.1E+2	1.4E+4	7.5E+3	3.3E+2	2.3E+4
I-129	8.7E-3	9.7E-2	4.4E-2	5.6E-2	5.7E-1	1.1E+0	2.7E-2	2.0E+0
Kr-85	1.4E+3	4.4E+3	4.8E+3	5.2E+3	4.2E+4	1.8E+5	8.9E+3	6.0E+5
Np-237	1.4E-2	1.7E+0	4.5E-1	1.9E-1	4.1E+0	2.2E+1	3.4E-1	3.4E+1
Pa-231	3.4E-4	2.0E-3	7.3E-3	2.0E-3	9.9E-3	2.7E-3	4.6E-5	3.5E-3
Pb-210	2.4E-9	3.5E-4	5.5E-5	8.4E-7	1.2E-5	6.4E-5	1.4E-6	8.7E-5
Pm-147	7.5E+3	1.7E+3	3.0E+4	1.0E+3	6.6E+3	1.4E+5	7.1E+4	4.2E+6
Pu-238	3.9E+0	3.1E+3	7.1E+3	8.0E+2	2.9E+4	7.8E+4	7.2E+2	1.1E+5
Pu-239	8.0E+0	5.7E+3	9.7E+2	1.6E+2	4.4E+3	7.4E+2	1.5E+1	1.3E+3

Table K-10. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 9 through 16[a,b] (page 2 of 2).

	Uranium oxide							
	Stainless steel clad (intact)		Not aluminum clad nonintact or declad			Aluminum clad		Uranium-aluminum
Radionuclide	HEU Group 9 (Ci)	LEU Group 10 (Ci)	HEU Group 11 (Ci)	MEU Group 12 (Ci)	LEU Group 13 (Ci)	HEU Group 14 (Ci)	MEU and LEU Group 15 (Ci)	HEU Group 16 (Ci)
Pu-240	1.0E+0	2.3E+3	6.7E+2	1.6E+2	5.5E+3	4.1E+2	8.8E+0	7.1E+2
Pu-241	1.8E+1	1.2E+5	1.1E+5	1.0E+4	5.2E+5	1.0E+5	2.2E+3	2.3E+5
Pu-242	2.4E-5	1.4E+0	5.6E+0	6.7E-1	2.3E+1	1.5E+0	1.3E-2	2.0E+0
Ra-226	8.5E-9	9.4E-4	1.5E-4	2.3E-6	4.2E-5	2.9E-4	4.8E-6	3.6E-4
Ra-228	9.2E-8	1.9E-5	1.4E-3	5.6E-7	4.3E-6	1.9E-8	2.3E-10	1.2E-6
Ru-106	3.8E+2	2.1E+0	1.6E+3	3.3E-2	2.7E-1	1.6E+3	5.1E+3	3.6E+5
Se-79	1.6E-1	2.7E+0	7.9E-1	9.5E-1	8.3E+0	1.9E+1	4.7E-1	3.4E+1
Sn-126	1.4E-1	2.0E+0	6.9E-1	9.8E-1	1.2E+1	1.7E+1	4.2E-1	3.0E+1
Sr-90	2.3E+4	1.2E+5	9.6E+4	1.2E+5	9.3E+5	3.0E+6	9.2E+4	6.5E+6
Tc-99	5.6E+0	4.7E+1	2.8E+1	3.3E+1	2.8E+2	6.2E+2	1.5E+1	1.1E+3
Th-229	1.0E-7	1.7E-4	4.0E-3	1.8E-6	3.4E-5	7.6E-6	1.1E-7	9.7E-6
Th-230	1.2E-6	8.6E-2	1.3E-2	2.2E-4	5.3E-3	5.2E-2	9.1E-4	6.8E-2
Th-232	9.9E-8	1.9E-5	1.4E-3	5.7E-7	4.4E-6	2.9E-8	4.2E-10	1.5E-6
Tl-208	2.9E-4	1.3E-2	2.0E-1	3.3E-3	7.6E-2	7.0E-2	1.6E-3	1.2E-1
U-232	8.0E-4	3.6E-2	5.4E-1	9.0E-3	2.1E-1	1.9E-1	4.7E-3	3.4E-1
U-233	3.7E-5	3.6E-2	8.2E-1	4.5E-4	9.7E-3	4.2E-3	7.8E-5	6.7E-3
U-234	4.4E-3	1.9E+2	2.9E+1	5.4E-1	1.7E+1	2.3E+2	6.6E+0	4.3E+2
U-235	2.7E-1	1.8E-1	2.4E+0	1.3E-1	4.6E+0	7.8E+0	6.2E-2	1.3E+1
U-236	1.9E-1	2.6E+0	9.8E-1	1.1E+0	7.5E+0	2.4E+1	5.6E-1	4.2E+1
U-238	1.9E-1	2.6E-1	3.6E-1	1.3E-1	2.7E+1	1.3E-1	8.3E-2	3.2E-1

a. LEU = low-enriched uranium; MEU = medium-enriched uranium; HEU = high-enriched uranium.

b. Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.

Table K-11. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 17 through 24[a,b] (page 1 of 2).

			Thorium/uranium carbide		Plutonium/ uranium carbide	Mixed oxide		
Radionuclide	Uranium-aluminum MEU Group 17 (Ci)	Uranium-silicide Group 18 (Ci)	TRISO or BISO particles in graphite Group 19 (Ci)	Mono-pyrolytic carbon particles Group 20 (Ci)	Not graphite nonsodium bonded Group 21 (Ci)	Zirconium clad Group 22 (Ci)	Stainless steel clad Group 23 (Ci)	Non-stainless steel non-zirconium clad Group 24 (Ci)
Ac-227	6.1E-5	2.7E-4	2.6E+0	2.3E-1	2.1E-8	1.6E-1	4.2E-2	4.9E-3
Am-241	1.9E+3	8.6E+3	2.3E+3	1.8E+2	8.9E+2	5.8E+5	2.5E+5	3.0E+4
Am-242m	1.3E+0	6.1E+0	2.2E+0	1.4E-1	1.7E+1	1.2E+3	2.1E+3	2.8E+2
Am-243	1.1E+0	4.4E+0	4.0E+1	2.7E+0	9.0E-1	1.1E+3	4.4E+2	6.1E+1
C-14	3.0E-2	1.2E+0	2.0E+1	1.4E+0	2.2E-1	8.3E+3	2.6E+3	3.7E+2
Cl-36	2.5E-5	1.2E-3	9.2E-1	6.2E-2	2.9E-6	1.6E+2	4.9E+1	7.0E+0
Cm-243	4.3E-1	2.0E+0	3.0E+1	1.5E+0	4.9E+0	7.7E+1	5.8E+2	7.4E+1
Cm-244	3.3E+1	1.3E+2	9.0E+3	3.8E+2	2.1E+1	1.2E+4	7.7E+3	1.2E+3
Co-60	3.0E+1	9.1E+2	2.3E+3	2.7E+1	8.9E+1	1.9E+6	3.5E+6	6.4E+5
Cs-134	1.3E+5	2.6E+5	3.7E+3	1.5E+1	2.0E+2	9.4E+1	4.1E+4	5.1E+3
Cs-135	1.3E+0	4.8E+0	2.1E+1	1.4E+0	4.0E-1	3.2E+1	4.9E+1	6.4E+0
Cs-137	9.1E+5	2.5E+6	1.5E+6	7.8E+4	1.6E+4	1.5E+6	2.3E+6	3.2E+5
Eu-154	2.4E+4	9.2E+4	3.9E+4	9.3E+2	3.0E+2	8.6E+4	1.1E+5	1.8E+4
Eu-155	1.1E+4	3.7E+4	5.9E+3	6.3E+1	3.8E+2	5.3E+3	6.7E+4	9.0E+3
Fe-55	1.0E+4	4.7E+4	1.6E+0	5.3E-3	2.6E+1	2.0E+4	4.8E+5	5.5E+4
H-3	3.3E+3	8.8E+3	6.9E+3	2.3E+2	6.0E+1	1.7E+4	1.7E+4	2.7E+3
I-129	2.4E-1	6.6E-1	8.7E-1	5.9E-2	1.1E-2	7.8E-1	1.3E+0	1.7E-1
Kr-85	8.7E+4	2.2E+5	7.9E+4	2.3E+3	4.7E+2	4.2E+4	8.5E+4	1.2E+4
Np-237	2.3E+0	4.7E+0	1.1E+1	7.3E-1	2.5E-2	1.1E+1	5.6E+0	7.6E-1
Pa-231	3.4E-4	1.2E-3	4.1E+0	2.8E-1	5.7E-8	2.0E-1	6.1E-2	8.7E-3
Pb-210	1.0E-6	1.2E-5	7.3E-4	8.3E-5	4.1E-9	1.6E-3	3.2E-4	1.1E-5
Pm-147	7.5E+5	1.8E+6	5.2E+3	1.7E+1	1.1E+3	1.9E+3	2.2E+5	2.8E+4
Pu-238	4.8E+3	8.8E+3	1.5E+5	9.5E+3	2.2E+2	1.5E+5	3.8E+4	3.0E+3

Table K-11. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 17 through 24[a,b] (page 2 of 2).

			Thorium/uranium carbide		Plutonium/ uranium carbide	Mixed oxide		
Radionuclide	Uranium-aluminum MEU Group 17 (Ci)	Uranium-silicide Group 18 (Ci)	TRISO or BISO particles in graphite Group 19 (Ci)	Mono-pyrolytic carbon particles Group 20 (Ci)	Not graphite nonsodium bonded Group 21 (Ci)	Zirconium clad Group 22 (Ci)	Stainless steel clad Group 23 (Ci)	Non-stainless steel non-zirconium clad Group 24 (Ci)
Pu-239	1.3E+3	6.7E+3	1.2E+2	7.9E+0	1.0E+3	2.2E+4	1.5E+5	0.0E+0
Pu-240	7.1E+2	3.5E+3	2.2E+2	1.6E+1	8.4E+2	1.3E+4	1.1E+5	3.9E+3
Pu-241	1.0E+5	4.9E+5	3.1E+4	1.1E+3	2.3E+4	1.3E+6	4.2E+6	2.6E+4
Pu-242	4.5E-1	2.0E+0	3.4E+0	2.3E-1	2.7E-1	1.3E+2	4.4E+1	1.8E+0
Ra-226	9.0E-6	4.7E-5	1.2E-3	1.6E-4	1.5E-8	4.4E-3	9.2E-4	5.1E-5
Ra-228	1.2E-7	4.9E-6	7.8E-1	5.4E-2	8.1E-13	4.1E-2	1.2E-2	1.7E-3
Ru-106	6.4E+4	1.7E+5	6.5E-1	7.9E-2	5.9E+1	7.4E-1	1.2E+4	1.5E+3
Se-79	4.1E+0	1.1E+1	1.8E+1	1.2E+0	8.5E-2	1.4E+1	1.3E+1	1.7E+0
Sn-126	3.7E+0	1.0E+1	1.9E+1	1.3E+0	3.7E-1	1.3E+1	4.0E+1	5.2E+0
Sr-90	8.6E+5	2.3E+6	1.5E+6	7.4E+4	5.8E+3	1.4E+6	1.2E+6	1.7E+5
Tc-99	1.4E+2	3.9E+2	2.9E+2	1.9E+1	3.3E+0	4.8E+2	4.8E+2	6.2E+1
Th-229	5.5E-7	5.1E-6	5.8E+0	6.2E-1	1.6E-8	1.2E-1	2.9E-2	2.7E-3
Th-230	3.6E-3	8.4E-3	1.2E-1	1.1E-2	3.1E-6	4.0E-1	9.6E-2	9.1E-3
Th-232	1.4E-7	6.4E-6	2.5E+0	1.7E-1	1.2E-12	4.1E-2	1.3E-2	1.8E-3
Tl-208	9.8E-3	1.7E-2	5.8E+2	3.5E+1	4.3E-3	6.0E+0	2.5E+0	3.7E-1
U-232	2.9E-2	4.8E-2	1.6E+3	9.4E+1	1.2E-2	1.6E+1	6.7E+0	1.0E+0
U-233	5.0E-4	4.3E-3	1.8E+3	1.2E+2	2.5E-6	2.5E+1	7.7E+0	1.1E+0
U-234	3.7E+1	4.7E+1	2.4E+2	1.7E+1	2.2E-2	8.7E+2	2.7E+2	3.9E+1
U-235	4.4E-1	1.2E+0	3.6E+0	2.4E-1	1.9E-4	4.0E+1	1.2E+1	1.8E+0
U-236	4.7E+0	1.2E+1	7.4E+0	5.0E-1	1.1E-3	1.6E+1	5.1E+0	7.3E-1
U-238	7.9E-1	2.2E+0	4.5E-2	3.0E-3	1.8E-2	8.0E+0	5.0E+0	3.9E-1

a. LEU = low-enriched uranium; MEU = medium-enriched uranium; HEU = high-enriched uranium.
b. Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.

Table K-12. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 25 through 34[a,b] (page 1 of 3).

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25 (Ci)	Stainless steel clad Group 26 (Ci)	HEU Group 27 (Ci)	MEU Group 28 (Ci)	MEU Group 29 (Ci)	Declad Group 30 (Ci)	Naval spent nuclear fuel Group 32[c] (Ci)	Miscellaneous Group 34 (Ci)
Ac-227	3.9E+1	7.4E+0	2.1E-5	6.5E-5	2.1E-5	2.7E-4	3.9E-2	5.0E-3
Am-241	1.1E+2	7.1E+3	3.8E+2	1.1E+2	3.0E+1	1.1E+2	2.0E+4	2.7E+3
Am-242m	7.3E-1	1.6E+1	8.2E-1	7.2E-2	1.9E-2	3.3E-2	1.8E+2	6.9E+0
Am-243	1.5E-1	1.5E+1	1.1E+0	7.7E-3	2.4E-3	4.2E-3	2.7E+2	1.5E+1
C-14	4.4E+1	1.2E+2	4.4E+0	6.7E+0	4.4E-1	3.6E+0	6.4E+3	3.9E+1
Cf-252	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	4.8E-4	0.0E+0
Cl-36	8.5E-1	2.2E+0	9.3E-2	1.5E-1	4.3E-4	8.0E-2	2.8E+2	7.0E-1
Cm-242	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	5.6E+2	0.0E+0
Cm-243	1.8E-1	1.0E+0	1.1E+0	8.8E-3	2.4E-3	1.7E-3	3.2E+2	8.1E-1
Cm-244	9.8E+0	2.2E+2	1.1E+2	8.2E-2	2.6E-2	8.6E-3	2.5E+4	5.4E+1
Cm-245	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	2.9E+0	0.0E+0
Cm-246	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	5.6E-1	0.0E+0
Cm-247	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	3.8E-6	0.0E+0
Cm-248	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.0E-5	0.0E+0
Co-60	1.5E+3	9.5E+4	2.3E+4	5.8E+4	2.2E+2	9.8E+1	1.5E+6	1.1E+4
Co-60 (Crud)	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	2.3E+3	0.0E+0
Cs-134	3.5E+2	1.1E+1	9.8E+3	4.0E+3	7.1E+2	7.0E-4	3.4E+7	8.8E+1
Cs-135	1.3E+1	2.6E+0	6.9E-1	1.7E+0	3.2E-1	9.1E-1	1.8E+3	4.4E+0
Cs-137	8.8E+5	1.4E+5	8.0E+4	1.4E+5	2.4E+4	2.8E+4	1.8E+8	2.1E+5
Eu-154	9.1E+3	3.2E+3	2.7E+3	7.1E+2	1.0E+4	1.2E+1	0.0E+0	5.1E+2
Eu-155	1.3E+3	3.0E+2	9.8E+2	1.3E+3	3.1E+3	1.6E+0	0.0E+0	2.3E+3
Fe-55	1.6E+1	3.8E+3	1.2E+4	3.4E+4	6.0E+1	1.4E-1	0.0E+0	3.7E+2
H-3	1.8E+3	5.5E+2	2.5E+2	5.2E+2	8.5E+1	2.5E+1	5.6E+5	1.1E+3
I-129	7.5E-1	1.3E-1	2.5E-2	3.8E-2	7.4E-3	2.1E-2	4.8E+1	1.1E-1
Kr-85	5.6E+4	5.8E+3	5.8E+3	1.2E+4	1.9E+3	3.9E+2	1.4E+7	1.3E+4

Table K-12. Radionuclide inventories in the year 2010 for DOE spent nuclear fuel groups 25 through 34[a,b] (page 2 of 3).

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25 (Ci)	Stainless steel clad Group 26 (Ci)	HEU Group 27 (Ci)	MEU Group 28 (Ci)	MEU Group 29 (Ci)	Declad Group 30 (Ci)	Naval spent nuclear fuel Group 32c (Ci)	Miscellaneous Group 34 (Ci)
Nb-93m	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.4E+3	0.0E+0
Nb-94	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	7.2E+4	0.0E+0
Ni-59	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	2.5E+4	0.0E+0
Ni-63	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	3.1E+6	0.0E+0
Np-237	5.9E-2	1.5E-1	4.2E-1	6.5E-2	1.5E-2	3.7E-2	6.4E+2	3.6E-1
Pa-231	5.7E+1	9.1E+0	5.3E-5	2.3E-4	5.6E-5	4.4E-4	2.1E-1	1.2E-2
Pb-210	5.6E-3	1.1E-3	1.9E-8	1.2E-9	9.8E-10	2.0E-8	3.6E-4	7.7E-6
Pd-107	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	2.4E+1	0.0E+0
Pm-147	1.7E+3	2.3E+2	1.8E+4	9.3E+4	1.4E+4	4.1E-1	0.0E+0	2.2E+4
Pu-238	2.2E+2	2.9E+3	1.8E+3	5.3E+1	1.3E+1	2.1E+1	4.8E+6	8.6E+2
Pu-239	1.3E+1	3.8E+2	4.9E+1	2.9E+2	5.7E+1	1.6E+2	4.8E+3	2.1E+3
Pu-240	7.6E+0	2.7E+2	4.0E+1	1.1E+2	2.3E+1	6.0E+1	5.6E+3	1.9E+2
Pu-241	1.1E+3	7.1E+4	1.1E+4	4.9E+3	1.0E+3	3.3E+2	1.6E+6	1.7E+4
Pu-242	1.9E-2	2.2E+0	1.7E-1	1.2E-2	3.1E-3	6.6E-3	3.2E+1	7.2E-1
Ra-226	6.8E-3	1.7E-3	7.8E-8	5.4E-9	3.0E-9	4.8E-8	2.2E-3	2.0E-5
Ra-228	2.2E+0	3.5E-1	7.3E-7	1.0E-5	2.0E-6	7.2E-6	7.2E-5	3.1E-4
Rh-102	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.1E+1	0.0E+0
Ru-106	1.8E-2	3.5E-3	1.4E+3	4.0E+3	6.4E+2	9.7E-11	2.4E+6	3.9E+1
Se-79	1.7E+1	2.9E+0	4.5E-1	6.8E-1	1.3E-1	3.7E-1	1.4E+2	1.6E+0
Sm-151	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	5.6E+5	0.0E+0
Sn-126	1.9E+1	3.2E+0	4.2E-1	6.3E-1	1.2E-1	3.5E-1	4.8E+2	3.6E+0
Sr-90	8.9E+5	1.4E+5	7.5E+4	1.3E+5	2.3E+4	2.5E+4	1.8E+8	1.9E+5
Tc-99	1.5E+2	3.1E+1	1.4E+1	2.3E+1	4.4E+0	1.3E+1	2.8E+4	4.5E+1
Th-229	2.2E+1	4.9E+0	5.1E-6	9.0E-6	2.7E-6	2.2E-5	3.8E-3	1.8E-3
Th-230	4.9E-1	9.0E-2	1.6E-5	1.2E-6	4.1E-7	3.7E-6	7.2E-1	1.9E-3

Table K-12. Radionuclide inventories in the Year 2010 for DOE spent nuclear fuel groups 25 through 34[a,b] (page 3 of 3).

			Uranium/zirconium hydride					
	Thorium/uranium oxide		Stainless steel/incoloy clad		Aluminum clad			
Radionuclide	Zirconium clad Group 25 (Ci)	Stainless steel clad Group 26 (Ci)	HEU Group 27 (Ci)	MEU Group 28 (Ci)	MEU Group 29 (Ci)	Declad Group 30 (Ci)	Naval spent nuclear fuel Group 32[c] (Ci)	Miscellaneous Group 34 (Ci)
Th-232	4.5E+0	8.0E-1	8.5E-7	1.3E-5	2.4E-6	7.2E-6	9.2E-5	2.7E-2
Tl-208	7.2E+3	1.1E+3	5.0E-3	8.7E-4	1.9E-4	3.4E-4	0.0E+0	4.5E-1
U-232	2.0E+4	2.9E+3	1.4E-2	2.5E-3	5.3E-4	9.1E-4	2.2E+2	1.2E+0
U-233	1.4E+4	2.5E+3	2.4E-3	6.3E-3	1.3E-3	3.5E-3	1.2E+0	8.7E+1
U-234	3.9E+2	7.4E+1	1.2E-1	8.7E-3	2.1E-3	8.1E-3	6.0E+3	4.4E+0
U-235	3.0E-2	5.3E-1	2.1E-1	5.0E-1	1.3E-1	2.6E-2	1.2E+2	2.1E-1
U-236	6.3E-2	2.2E-1	4.7E-1	6.6E-1	1.3E-1	3.6E-1	1.0E+3	1.3E+0
U-238	1.8E-3	1.1E-1	1.6E-2	3.9E-1	9.7E-2	1.5E-2	4.8E-1	8.6E-2
Zr-93	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	4.4E+3	0.0E+0

a. LEU = low-enriched uranium; MEU = medium-enriched uranium; HEU = high-enriched uranium.

b. Source: Compiled from data contained in DIRS 169354-DOE 2004, Volume II, Appendix C.

c. Radionuclide inventory is for 400 casks. Single cask naval spent fuel inventory is from DIRS 155857-McKenzie 2001, Table 3.

Note: There would be no shipments of group 31 or group 33 spent nuclear fuel under the Proposed Action.

Table K-13. Radionuclide inventories for commercial spent nuclear fuel shipped in rail casks.[a]

Radionuclide	Pressurized-water-reactor commercial spent nuclear fuel assembly inventory (Ci)[b]	Pressurized-water-reactor commercial spent nuclear fuel total inventory (Ci)[b]	Boiling-water-reactor commercial spent nuclear fuel assembly inventory (Ci)[c]	Boiling-water-reactor commercial spent nuclear fuel total inventory (Ci)[c]
Am-241	1.28E+03	1.11E+08	3.73E+02	4.61E+07
Am-242m	7.99E+00	6.96E+05	2.88E+00	3.56E+05
Am-243	3.93E+01	3.42E+06	8.63E+00	1.07E+06
C-14	4.35E-01	3.79E+04	1.69E-01	2.09E+04
Cd-113m	2.34E+01	2.03E+06	6.23E+00	7.69E+05
Ce-144	6.99E+01	6.09E+06	1.73E+01	2.14E+06
Cm-242	6.60E+00	5.75E+05	2.38E+00	2.94E+05
Cm-243	2.48E+01	2.16E+06	5.55E+00	6.86E+05
Cm-244`	5.85E+03	5.09E+08	9.23E+02	1.14E+08
Cm-245	8.16E-01	7.10E+04	9.07E-02	1.12E+04
Cm-246	4.07E-01	3.54E+04	4.26E-02	5.26E+03
Co-60	2.17E+03	1.89E+08	1.14E+02	1.41E+07
Co-60 (Crud)	1.69E+01	1.47E+06	5.66E+01	6.99E+06
Cs-134	5.43E+03	4.73E+08	1.31E+03	1.62E+08
Cs-137	7.16E+04	6.23E+09	2.41E+04	2.98E+09
Eu-154	3.01E+03	2.62E+08	7.79E+02	9.62E+07
Eu-155	6.42E+02	5.59E+07	1.93E+02	2.39E+07
Fe-55 (Crud)	2.09E+02	1.82E+07	9.84E+01	1.22E+07
H-3	3.05E+02	2.66E+07	1.05E+02	1.30E+07
I-129	2.76E-02	2.40E+03	9.22E-03	1.14E+03
Kr-85	3.39E+03	2.95E+08	1.17E+03	1.45E+08
Np-237	2.94E-01	2.56E+04	8.74E-02	1.08E+04
Pm-147	6.06E+03	5.28E+08	2.11E+03	2.61E+08
Pu-238	3.98E+03	3.46E+08	1.02E+03	1.26E+08
Pu-239	1.75E+02	1.52E+07	5.41E+01	6.68E+06
Pu-240	3.63E+02	3.16E+07	1.27E+02	1.57E+07
Pu-241	5.64E+04	4.91E+09	1.57E+04	1.94E+09
Pu-242	2.48E+00	2.16E+05	7.08E-01	8.75E+04
Ru-106	4.04E+02	3.52E+07	9.05E+01	1.12E+07
Sb-125	5.20E+02	4.53E+07	1.45E+02	1.79E+07
Sr-90	4.51E+04	3.93E+09	1.66E+04	2.05E+09
U-232	3.61E-02	3.14E+03	8.74E-03	1.08E+03
U-234	5.24E-01	4.56E+04	2.39E-01	2.95E+04
U-236	1.77E-01	1.54E+04	7.45E-02	9.20E+03
U-238	1.46E-01	1.27E+04	6.24E-02	7.71E+03

a. Sources: DIRS 169061-BSC 2004, all; DIRS 164364-BSC 2003, all.

b. Total inventory for pressurized-water-reactor spent nuclear fuel shipped in rail casks is based on 87,057 assemblies (calculated from rail shipments and cask capacities from DIRS 181377-BSC 2007, Section 7).

c. Total inventory for boiling-water-reactor spent nuclear fuel shipped in rail casks is based on 123,537 assemblies (calculated from rail shipments and cask capacities from DIRS 181377-BSC 2007, Section 7).

Table K-14. Radionuclide inventories for high-level radioactive waste (page 1 of 2).

Radionuclide	Hanford high-level radioactive waste[a] (Ci)	Idaho high-level radioactive waste[b] (Ci)	Savannah River Site high-level radioactive waste[c] (Ci)	West Valley high-level radioactive waste[d] (Ci)
Ac-227	7.38E+1	0.00E+0	0.00E+0	1.03E+1
Am-241	1.08E+5	5.87E+3	1.17E+6	5.84E+4
Am-242m	0.00E+0	6.93E-3	2.72E+2	3.15E+2
Am-243	1.13E+1	6.42E-3	4.80E+3	3.79E+2
C-14	0.00E+0	1.28E+0	0.00E+0	1.49E+2
Cd-113m	7.76E+3	0.00E+0	9.17E-8	1.75E+3
Ce-144	0.00E+0	0.00E+0	1.34E+4	3.39E-3
Cf-249	0.00E+0	0.00E+0	8.19E+1	0.00E+0
Cf-251	0.00E+0	0.00E+0	6.48E+1	0.00E+0
Cm-242	0.00E+0	5.73E-3	0.00E+1	2.60E+2
Cm-243	8.28E+0	2.17E-4	1.48E+3	1.27E+2
Cm-244	1.57E+2	4.76E-3	1.53E+6	6.62E+3
Cm-245	0.00E+0	1.71E-6	8.47E+1	9.61E-1
Cm-246	0.00E+0	4.00E-8	1.02E+2	1.10E-1
Cm-247	0.00E+0	1.43E-14	7.70E+1	0.00E+0
Cm-248	0.00E+0	4.32E-15	0.00E+0	0.00E+0
Co-60	1.87E+3	1.48E+1	6.51E+5	3.81E+2
Cs-134	6.71E+2	1.52E-2	6.83E+5	7.49E+2
Cs-135	0.00E+0	7.53E+1	7.56E+2	1.76E+2
Cs-137	2.80E+7	2.75E+6	1.94E+8	6.86E+6
Eu-152	7.76E+2	0.00E+0	0.00E+0	2.93E+2
Eu-154	5.03E+4	2.76E+3	1.47E+6	6.45E+4
Eu-155	1.82E+3	3.49E+0	2.38E+3	1.12E+4
Fe-55	0.00E+0	0.00E+0	0.00E+0	1.55E+2
H-3	0.00E+0	1.65E+3	0.00E+0	6.40E+1
I-129	3.61E+1	2.61E+0	1.13E+0	2.29E-1
Nb-93m	2.00E+3	2.19E+2	5.22E+2	2.26E+2
Nb-94	0.00E+0	2.48E-3	0.00E+0	0.00E+0
Ni-59	1.03E+3	0.00E+0	2.95E+3	1.16E+2
Ni-63	9.04E+4	0.00E+0	2.80E+5	8.91E+3
Np-236	0.00E+0	0.00E+0	0.00E+0	1.03E+1
Np-237	1.06E+2	2.89E+0	1.01E+2	2.56E+1
Pa-231	2.05E+2	0.00E+0	0.00E+0	1.66E+1
Pd-107	0.00E+0	0.00E+0	4.59E+0	1.20E+1
Pm-146	0.00E+0	0.00E+0	0.00E+0	5.57E+0
Pm-147	0.00E+0	1.23E+1	7.77E+6	1.96E+4
Pu-236	0.00E+0	0.00E+0	0.00E+0	9.20E-1
Pu-238	3.43E+3	4.15E+4	3.45E+6	8.77E+3
Pu-239	5.20E+4	8.37E+2	6.09E+4	1.80E+3
Pu-240	9.26E+3	7.26E+2	2.94E+4	1.33E+3
Pu-241	6.10E+4	8.92E+3	2.95E+6	6.69E+4
Pu-242	7.53E-1	1.58E+0	7.49E+1	1.80E+0
Ra-226	6.78E-2	4.48E-3	0.00E+0	0.00E+0
Ra-228	1.58E+1	0.00E+0	0.00E+0	1.72E+0

Table K-14. Radionuclide inventories for high-level radioactive waste (page 2 of 2).

Radionuclide	Hanford high-level radioactive waste[a] (Ci)	Idaho high-level radioactive waste[b] (Ci)	Savannah River Site high-level radioactive waste[c] (Ci)	West Valley high-level radioactive waste[d] (Ci)
Rh-102	0.00E+0	9.20E-6	0.00E+0	0.00E+0
Ru-106	1.51E+0	0.00E+0	1.53E+4	2.52E-1
Sb-125	1.86E+3	4.76E-1	4.20E+5	1.77E+3
Se-79	9.19E+1	0.00E+0	1.87E+3	6.57E+1
Sm-151	2.46E+6	0.00E+0	5.64E+5	8.78E+4
Sn-121m	0.00E+0	0.00E+0	6.79E+3	1.76E+1
Sn-126	4.36E+2	4.12E+1	2.74E+3	1.13E+2
Sr-90	3.07E+7	3.25E+6	1.20E+8	6.34E+6
Tc-99	2.24E+4	1.58E+3	3.21E+4	1.85E+3
Th-228	0.00E+0	0.00E+0	0.00E+0	9.40E+0
Th-229	1.51E+0	0.00E+0	3.11E-1	2.35E-1
Th-230	0.00E+0	1.83E-1	2.79E-2	6.40E-2
Th-232	6.02E+0	4.57E-8	4.90E+0	1.79E+0
U-232	3.01E+1	2.14E-3	1.04E+0	7.49E+0
U-233	3.84E+2	6.15E-4	1.96E+2	1.04E+1
U-234	1.66E+2	4.60E+1	1.58E+2	5.03E+0
U-235	6.78E+0	2.73E-1	1.32E+0	1.10E-1
U-236	4.52E+0	7.12E-1	1.28E+1	3.23E-1
U-238	1.50E+2	1.36E-2	1.66E+2	9.32E-1
Zr-93	3.62E+3	0.00E+0	1.35E+3	2.97E+2

a. The Hanford high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 5,325 canisters (DIRS 181377-BSC 2007, Section 7; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 8).

b. The Idaho high-level radioactive waste radionuclide inventory represents the radionuclide inventory in 550 canisters (DIRS 181377-BSC 2007, Section 7; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 17).

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; based on radionuclide inventory from DIRS 184907-BSC 2008, 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; based on radionuclide inventory from DIRS 184907-BSC 2008, Table 15).

K.2.4.3 Conditional Probabilities and Release Fractions

In this appendix, 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. Table K-15 lists these spent nuclear fuel groups. Commercial spent nuclear fuel is organized into two groups, pressurized-water-reactor spent nuclear fuel and boiling-water-reactor spent nuclear fuel. High-level radioactive waste is organized into four groups, Idaho high-level waste, Hanford high-level waste, Savannah River high-level radioactive waste, and West Valley high-level radioactive waste. These groups were assigned to a set of 10 conditional probabilities and release fractions known as release fraction groups based on the characteristics and behaviors of the spent nuclear fuel or high-level radioactive waste (see Tables K-16 through K-28). Release fractions were specified for inert gases, volatile constituents such as cesium and ruthenium, particulates, and activation products such as Co-60 that were deposited on the exterior surfaces of the spent nuclear fuel (also known as crud).

For loss of shielding accidents, the Rail Alignment EIS uses unit risk factors for six severity categories of accidents (DIRS 155970-DOE 2002, p. J-54, Table J-19). These unit risk factors are listed in Tables K-27 and K-28.

Tables K-16 through K-26 also list “one-group” release fractions. One-group release fractions are defined as the sum of the products of the conditional probability and release fraction for all six accident severity categories:

$$\text{One-Group Release Fraction} = \sum_{\text{Severity Category, } i=1}^{6} \text{Conditional Probability}_i \times \text{Release Fraction}_i$$

Similarly, the one-group unit risk factors listed in Tables K-27 and K-28 are defined as the sum of the products of the conditional probability and unit risk factor for all six accident severity categories:

$$\text{One-Group Unit Risk Factor} = \sum_{\text{Severity Category, } i=1}^{6} \text{Conditional Probability}_i \times \text{Unit Risk Factor}_i$$

The conditional probabilities and release fractions listed in Tables K-16 through K-28 would be mostly a direct consequence of error on the part of transport vehicle operators, operators of other vehicles, or people who maintain vehicles and rights-of-way. The number and severity of the accidents would be minimized through the use of trained and qualified personnel.

K.2.4.3.1 Human Error and Transportation Accidents

Several types of human error could be involved in transportation, some of which could contribute to accident consequences. One type of human error that could contribute to accident consequences would be errors involving transport vehicle operators, operators of other vehicles, or persons who maintained vehicles and rights-of-way. The accident rates (see Section K.2.4.1) and conditional probabilities and release fractions (see Section K.2.4.3) used to estimate the risks and consequences from accidents involving rail shipments account for this type of human error. The doses and associated health effects to workers and the public are presented in Sections 4.2.10 and 4.3.10.

The State of Nevada suggested that other types of human error could contribute to accident consequences including: (1) errors in the preparation of the casks (packages) for shipment, (2) undetected errors in the design of transportation casks, and (3) undetected defects during the manufacture of casks. In addition,

Table K-15. Spent nuclear fuel groups, spent nuclear fuel descriptions, and release fraction groups (page 1 of 2).

Spent nuclear fuel group	Description	Release fraction group
1	Uranium metal, zirconium clad, low-enriched uranium	1
2	Uranium metal, non-zirconium clad, low-enriched uranium	1
3	Uranium-zirconium	1
4	Uranium-molybdenum	1
5	Uranium oxide, zirconium clad (intact), high-enriched uranium	2
6	Uranium oxide, zirconium clad (intact), medium-enriched uranium	2
7	Uranium oxide, zirconium clad (intact), low-enriched uranium	2
8	Uranium oxide, stainless steel/hastelloy clad (intact), high-enriched uranium	2
9	Uranium oxide, stainless steel clad (intact), medium-enriched uranium	2
10	Uranium oxide, stainless steel clad (intact), low-enriched uranium	2
11	Uranium oxide, non-aluminum clad (nonintact or declad), high-enriched uranium	3
12	Uranium oxide, non-aluminum clad (nonintact or declad), medium-enriched uranium	3
13	Uranium oxide, non-aluminum clad (nonintact or declad), low-enriched uranium	3
14	Uranium oxide, aluminum clad, high-enriched uranium	3
15	Uranium oxide, aluminum clad, medium-enriched uranium and low-enriched uranium	3
16	Uranium-aluminum, high-enriched uranium	4
17	Uranium-aluminum, medium-enriched uranium	4
18	Uranium-silicide	4
19	Thorium/uranium carbide, TRISO- or BISO-coated particles in graphite	5
20	Thorium/uranium carbide, mono-pyrolytic carbon-coated articles in graphite	6
21	Plutonium/uranium carbide, nongraphite clad, not sodium bonded	3
22	Mixed oxide, zirconium clad	2
23	Mixed oxide, stainless steel clad	2
24	Mixed oxide, non-stainless steel/non-zirconium clad	2
25	Thorium/uranium oxide, zirconium clad	2
26	Thorium/uranium oxide, stainless steel clad	2
27	Uranium-zirconium hydride, stainless steel/incoloy clad, high-enriched uranium	7
28	Uranium-zirconium hydride, stainless steel/incoloy clad, medium-enriched uranium	7
29	Uranium-zirconium hydride, aluminum clad, medium-enriched uranium	7
30	Uranium-zirconium hydride, aluminum clad, declad	7

Table K-15. Spent nuclear fuel groups, spent nuclear fuel descriptions, and release fraction groups (page 2 of 2).

Spent nuclear fuel group	Description	Release fraction group
31[a]	Metallic sodium bonded	–
32	Naval spent nuclear fuel	Navy
33[a]	Canyon stabilization	–
34	Miscellaneous	1
PWR	Pressurized-water reactor	PWR
BWR	Boiling-water reactor	BWR
HLW	Hanford, Idaho, Savannah River Site, and West Valley high-level radioactive waste	HLW

a. Under the Proposed Action in the Rail Alignment EIS, there would be no shipments of DOE groups 31 and 33 spent nuclear fuel.

Table K-16. Accident severity categories, conditional probabilities, and release fractions for commercial pressurized-water-reactor spent nuclear fuel (PWR Release Fraction Group).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	1.96E-1	5.87E-9	1.34E-7	1.34E-7	1.37E-3
3	4.91E-5	8.39E-1	1.68E-5	2.52E-7	2.52E-7	9.44E-3
4	5.77E-7	8.00E-1	8.71E-6	1.32E-5	1.32E-5	4.42E-3
5	1.10E-7	8.35E-1	3.60E-5	1.37E-5	1.37E-5	5.36E-3
6	8.52E-10	8.47E-1	5.71E-5	4.63E-5	1.43E-5	1.59E-2
one-group	--	4.93E-5	8.34E-10	2.67E-11	2.67E-11	5.20E-7

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-26.

Table K-17. Accident severity categories, conditional probabilities, and release fractions for commercial boiling-water-reactor spent nuclear fuel (BWR Release Fraction Group).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	2.35E-2	7.04E-10	1.47E-8	1.47E-8	5.59E-4
3	4.91E-5	8.39E-1	1.68E-5	2.52E-7	2.52E-7	9.44E-3
4	5.77E-7	8.00E-1	8.71E-6	1.32E-5	1.32E-5	4.42E-2
5	1.10E-7	8.37E-1	4.12E-5	1.82E-5	1.82E-5	5.43E-3
6	8.52E-10	8.45E-1	7.30E-5	5.94E-5	1.96E-5	1.60E-2
one-group	--	4.27E-5	8.35E-10	2.26E-11	2.26E-11	5.11E-7

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-27.

Table K-18. Accident severity categories, conditional probabilities, and release fractions for naval spent nuclear fuel (Navy Release Fraction Group).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99996	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	4.02E-5	1.52E-2	4.55E-9	9.10E-9	9.10E-9	1.37E-3
3	6.32E-6	8.39E-2	1.68E-6	2.52E-8	2.52E-8	9.44E-3
4	1.22E-7	8.00E-2	8.98E-7	1.34E-6	1.34E-6	4.47E-2
5	1.51E-8	9.44E-2	4.00E-6	1.80E-6	1.80E-6	5.36E-3
6	1.66E-10	9.04E-2	5.49E-6	4.67E-6	1.93E-6	2.86E-2
one-group	--	1.15E-6	1.10E-11	7.17E-13	7.16E-13	1.20E-7

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-46.

Table K-19. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel groups 1, 2, 3, 4, and 34 (Release Fraction Group 1).[a]

Accident severity category	Conditional probability	Release Fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	2.84E-4	1.71E-6	3.91E-7	1.10E-8	2.96E-5
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	2.13E-3	2.36E-6	3.55E-6	3.55E-6	1.18E-2
5	1.10E-7	4.00E-3	7.87E-5	1.77E-5	9.68E-8	1.61E-4
6	8.52E-10	4.68E-2	9.63E-4	2.47E-4	2.73E-6	7.17E-3
one-group	--	1.27E-8	7.69E-11	1.93E-11	2.49E-12	8.00E-9

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-33.

Table K-20. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel groups 5, 6, 7, 8, 9, 10, 22, 23, 24, 25, and 26 (Release Fraction Group 2).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	1.96E-1	5.87E-9	1.34E-7	1.34E-7	1.37E-3
3	4.91E-5	8.39E-1	1.68E-5	2.52E-7	2.52E-7	9.44E-3
4	5.77E-7	8.00E-1	8.71E-6	1.32E-5	1.32E-5	4.42E-3
5	1.10E-7	8.35E-1	3.60E-5	1.37E-5	1.37E-5	5.36E-3
6	8.52E-10	8.47E-1	5.71E-5	4.63E-5	1.43E-5	1.59E-2
one-group	--	4.93E-5	8.34E-10	2.67E-11	2.67E-11	5.20E-7

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-26.

Table K-21. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel groups 11, 12, 13, 14, 15, and 21 (Release Fraction Group 3).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	1.15E-4	3.44E-10	7.15E-9	7.15E-9	2.38E-5
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	2.13E-3	2.36E-6	3.55E-6	3.55E-6	1.18E-2
5	1.10E-7	4.00E-3	3.14E-7	9.68E-8	9.68E-8	1.61E-4
6	8.52E-10	1.67E-2	2.68E-6	2.29E-6	2.04E-6	6.15E-3
one-group	--	6.12E-9	1.41E-12	2.34E-12	2.34E-12	7.78E-9

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-35.

Table K-22. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel groups 16, 17, and 18 (Release Fraction Group 4).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	2.84E-4	8.53E-5	1.10E-8	1.10E-8	4.11E-5
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	2.13E-3	2.36E-6	3.55E-6	3.55E-6	1.18E-2
5	1.10E-7	4.00E-3	3.53E-3	9.68E-8	9.68E-8	4.26E-4
6	8.52E-10	4.68E-2	2.92E-2	2.73E-6	2.73E-6	1.03E-2
one-group	--	1.27E-8	3.72E-9	2.49E-12	2.49E-12	8.48E-9

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-39.

Table K-23. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel group 19 (Release Fraction Group 5).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	1.02E-4	6.12E-11	6.12E-11	6.12E-11	0.00E+0
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	4.77E-3	7.89E-8	7.89E-8	7.89E-8	0.00E+0
5	1.10E-7	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
6	8.52E-10	1.70E-3	2.84E-8	2.62E-8	2.62E-8	0.00E+0
one-group	--	6.70E-9	4.79E-14	4.79E-14	4.79E-14	0.00E+0

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-41.

Table K-24. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel group 20 (Release Fraction Group 6).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	5.14E-1	3.70E-7	3.70E-7	3.70E-7	0.00E+0
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	4.77E-1	7.89E-6	7.89E-6	7.89E-6	0.00E+0
5	1.10E-7	7.64E-1	6.32E-6	5.73E-7	5.73E-7	0.00E+0
6	8.52E-10	7.45E-1	7.57E-6	5.82E-6	3.02E-6	0.00E+0
one-group	--	2.02E-5	1.96E-11	1.89E-11	1.89E-11	0.00E+0

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-43.

Table K-25. Accident severity categories, conditional probabilities, and release fractions for DOE spent nuclear fuel groups 27, 28, 29, and 30 (Release Fraction Group 7).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	1.15E-4	3.44E-8	7.15E-7	7.15E-7	2.38E-5
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	2.13E-3	2.36E-4	3.55E-4	3.55E-4	1.18E-2
5	1.10E-7	1.97E-2	1.97E-2	8.99E-5	1.93E-6	7.15E-4
6	8.52E-10	7.98E-2	7.91E-2	5.43E-4	1.76E-4	8.58E-3
one-group	--	7.91E-9	2.37E-9	2.43E-10	2.33E-10	7.84E-9

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-45.

Table K-26. Accident severity categories, conditional probabilities, and release fractions for Idaho, Hanford, and Savannah River Site high-level radioactive waste (HLW Release Fraction Group).[a]

Accident severity category	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
1	0.99991	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
2	3.87E-5	0.00E+0	6.22E-8	6.22E-8	6.22E-8	0.00E+0
3	4.91E-5	0.00E+0	0.00E+0	0.00E+0	0.00E+0	0.00E+0
4	5.77E-7	0.00E+0	7.89E-6	7.89E-6	7.89E-6	0.00E+0
5	1.10E-7	0.00E+0	9.29E-8	9.29E-8	9.29E-8	0.00E+0
6	8.52E-10	0.00E+0	2.74E-6	2.74E-6	2.74E-6	0.00E+0
one-group	--	0.00E+0	6.97E-12	6.97E-12	6.97E-12	0.00E+0

a. Source: DIRS 157144-Jason Technologies 2001, Table 5-48.

Table K-27. Accident severity categories, conditional probabilities, and unit risk factors for loss of shielding accidents for steel-lead-steel rail casks.[a]

Accident severity category	Conditional probability	Unit risk factor (person-rem per people/km^2)[b]
1	0.9999	3.86E-5
2	6.44E-6	7.22E-3
3	4.90E-5	2.03E-3
4	4.46E-7	1.24E-2
5	2.37E-5	2.41E-3
6	5.18E-9	2.97E-2
one-group	--	3.88E-5

a. Source: DIRS 155970-DOE 2002, Table J-19.

b. km^2 = square kilometer; to convert person-rem per people/square kilometer to person-rem per people/square mile, multiply by 0.38610.

Table K-28. Accident severity categories, conditional probabilities, and unit risk factors for loss of shielding accidents for monolithic steel rail casks.[a]

Accident severity category	Conditional probability	Unit risk factor (person rem per people/km^2)[b]
1	1.0000	3.86E-5
2	0	3.86E-5
3	0	3.86E-5
4	0	3.86E-5
5	0	3.86E-5
6	0	3.86E-5
one-group	--	3.86E-5

a. Source: DIRS 155970-DOE 2002, Table J-19.

b. km^2 = square kilometer; to convert person-rem per people/square kilometer to person-rem per people/square mile, multiply by 0.38610.

the state suggested that willful violations of regulations and procedures that guide the design and fabrication of casks, and the preparation of casks for shipment could exacerbate accident consequences. The exact nature of human error and whether such incidents were to occur singly or in combination are inherently uncertain—the possibilities are endless.

Errors in cask preparation, for example, could involve, either singly or in combination, defective tie-down bolts or bolts that are tightened insufficiently (or over-tightened), defective or loose or over-tightened cask lid bolts, use of unapproved or obsolete lid seals, and faulty test procedures. Even so, when considered as a category, the error rate for cask preparation and loading is estimated to be about 1 in 1,000 (DIRS 185491-Hughes, Roberts, and Watson 2006, all; DIRS 185493-Longfellow and Haslett 2002, all). For rail shipments of commercial spent nuclear fuel (three to five casks per shipment), the probability of any accident occurring would range from about 1 in 300 to 1 in 400 shipments, and when coupled with an error in cask preparation or loading would be about 1 chance in 80,000 shipments to about 1 chance in 90,000 shipments. Since DOE would make about 2,833 rail shipments of commercial spent nuclear fuel and high-level radioactive waste (under the Proposed Action), an accident involving rail casks that were not properly loaded or prepared for shipping would be very unlikely and therefore not expected to occur.

Errors in the design and fabrication of casks, or in the willful violation during such design and fabrication, could occur singly or in various combinations. To demonstrate, *A Review of the Effects of*

Human Error on the Risks Involved in Spent Fuel Transportation (DIRS 185494-Audin 1987, pp. 19 to 24) identifies more than 20 separate human error scenarios involving cask design, manufacturing and maintenance, and the ways in which accidents could be handled.

DOE is required, pursuant to the NWPA, to use casks that have been certified by the NRC to ship spent nuclear fuel and high-level radioactive waste. The procedures by which NRC certifies a cask design are described in the *Standard Review Plan for Transportation Packages for Spent Nuclear Fuel* (DIRS 154000-NRC 2000, all). Detailed evaluations are required to be conducted of the cask's structural and thermal design, containment system, shielding, and the ability of the cask to satisfy criticality safety requirements. The NRC does not require a "human reliability analysis" as a means to address human error when certifying a cask (a relatively passive containment device), as it does for more complex systems involving the handling of spent nuclear fuel, such as a commercial reactor or the proposed Yucca Mountain Repository.

Further, DOE has committed in its Record of Decision (69 *FR* 18557) that it would follow NRC regulations related to the shipping of spent nuclear fuel and high-level radioactive waste. These regulations address cask operating procedures, cask acceptance tests, and cask maintenance programs. The NRC requires procedures for loading and unloading a cask, acceptance tests to ensure that casks are fabricated in accordance with the design, and inspections to detect cracks, pinholes, uncontrolled voids, or other defects (for example, visual inspections and measurements, weld inspections, structural and pressure tests, leakage tests, shielding tests, neutron absorber tests, and thermal tests).

In addition, the NRC has issued quality assurance requirements related to the design, manufacturing, and use of casks, and requirements for inspections of transportation activities. The requirements for these quality assurance programs are contained in 10 CFR Part 71, Subpart H. Guidance for establishing these quality assurance programs is contained in NRC Regulatory Guide 7.10, *Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material* (DIRS 185496-NRC 2005, all).

The NRC also requires inspections of the manufacturers of spent nuclear fuel casks. The procedures for carrying out these inspections, which are described in *Quality Assurance Inspections for Shipping and Storage Containers* (DIRS 185497-NRC 1996, all), address management controls, design controls, fabrication controls, and maintenance controls. Inspections are required to verify that all phases of the fabrication process are controlled and implemented, and the fabrication process is required to be controlled and verifiable from the onset of design through the completion of the manufacturing process. NRC Inspection Procedure 86001, *Design, Fabrication, Testing, and Maintenance of Transportation Packaging* (DIRS 185498-NRC 2008, all), would be used to conduct these inspections. Inspections of manufacturers of spent nuclear fuel casks would involve observing these activities to verify that they are performed in accordance with approved methods, procedures, and specifications, and that the individuals performing these activities are properly trained and qualified.

Regarding the shipment of spent nuclear fuel and high-level radioactive waste to the repository in NRC-certified casks, DOE would meet or exceed NRC requirements related to the inspection of transportation activities. The NRC's procedures for carrying out inspections of transportation activities are described in NRC Inspection Procedure 86740, *Inspection of Transportation Activities* (DIRS 185499-NRC 2002, all). These procedures involve observations of the preparation of spent nuclear fuel casks for shipment, delivery of spent nuclear fuel casks to carriers, and receipt of spent nuclear fuel casks to verify that they are performed in accordance with approved methods, procedures, and specifications, and that the individuals performing these activities are properly trained and qualified.

DOE's analysis of potential accidents considers low probability-high consequence scenarios, including the most severe accidents that reasonably could occur (see Sections K.2.4 and K.2.5). DOE could analyze additional accident scenarios involving a combination of an extremely unlikely accident scenario compounded by human error, such as faulty welds or failed seals. DOE also could analyze accident scenarios involving other combinations of factors, such as multiple rail casks on a train having the same undetected design flaw and in which each cask had been fabricated improperly. As with any aspect of environmental impact analysis, it is always possible to postulate scenarios that could produce higher consequences than previous estimates. In eliminating the requirement that agencies conduct a worst-case analysis, the Council on Environmental Quality has pointed out that "one can always conjure up a worse 'worst case'" by adding more variables to a hypothetical event (50 *FR* 32234, August 8, 1985), but that "'worst case analysis' is an unproductive and ineffective method … one which can breed endless hypothesis and speculation" (51 *FR* 15620, April 25, 1986).

The Council on Environmental Quality regulations that implement NEPA require federal agencies to address reasonably foreseeable, significant adverse effects. The evaluation of impacts, however, is subject to a "rule of reason" designed to ensure analyses are based on credible scientific evidence that is useful to the decisionmaking process. In applying the rule of reason, an agency need not address remote and highly speculative consequences in its EIS. Because accidents involving a release of radioactive material from rail casks that were not properly loaded or prepared for shipping are so improbable for the reasons discussed above, under the rule of reason DOE did not consider such accidents.

K.2.4.4 Atmospheric Conditions

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 Rail Alignment EIS. The accident calculation methodology includes a probabilistic component that includes the atmospheric stability; therefore, DOE assumed neutral conditions. Atmospheric conditions affect the dispersion of radionuclides that could be released during an accident. Neutral weather conditions are typified by moderate wind speeds, vertical mixing within 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).

K.2.4.5 Population Density Zones

DOE used three population density zones (urban, rural, and suburban) for the transportation risk assessment. The Department defined urban areas as areas with a population density greater than 1,284 people per square kilometer (3,326 people per square mile); rural areas as areas with a population density less than 54 people per square kilometer (139 people per square mile); and suburban areas as areas with a population density between 54 and 1,284 people per square kilometer (139 and 3,326 people per square mile). The Department based the actual population densities, which Table K-2 lists, on 2000 census data. The radiological impacts were escalated to the year 2067 using the escalation factors listed in Table K-4.

K.2.4.6 Exposure Pathways

DOE calculated radiological doses for an individual located 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).

K.2.4.7 Unit Risk Factors and Radiation Dosimetry

As discussed in this section, DOE estimated the radiation doses from transportation accidents using unit risk factors. The Department estimated unit risk factors using the RADTRAN 5 computer code (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430-Neuhauser, Kanipe, and Weiner 2000, all) for five pathways: (1) ingestion, (2) inhalation, (3) immersion, (4) resuspension, and (5) groundshine. Table K-29 lists the unit risk factors.

DOE estimated the unit risk factors listed in Table K-29 using the ICRP inhalation and ingestion dose coefficients (DIRS 172935-ICRP 2001, all) and the EPA groundshine and immersion dose coefficients (DIRS 175544-EPA 2002, all). These dose coefficients are based on the recommendations by the International Commission on Radiological Protection in ICRP Publication 60 (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from ICRP Publication 72 (DIRS 152446-ICRP 1996, all). For each radionuclide, the dose coefficients used to estimate the unit risk factors in Table K-29 are listed in DIRS 176975-BMI 2006, Table 5 and include radioactive progeny (DIRS 176975-BMI 2006, Table 2). The lung absorption type and the value for the fractional absorption to blood from the small intestine (f_1) for each radionuclide are also listed in DIRS 176975-BMI 2006, Table 5.

Accident transportation unit risk factors were calculated using the RADTRAN 5 computer code. As in the incident-free transportation analysis, using unit risk factors simplifies the analysis of transportation risks and also improves its transparency and traceability.

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 mile) that could result if one 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 where 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 might remain intact, unit risk factors provide estimates of the resulting radiation dose to a person in a surrounding unit area after an accident.

K.2.4.8 Accidents Involving Hazardous Chemicals

DOE would ship spent nuclear fuel and high-level radioactive waste on the proposed rail line using dedicated trains, and hazardous chemical cargos would not be present on the same train as the spent nuclear fuel or high-level radioactive waste. In addition, trains carrying other materials to or from the repository would pull off onto sidings to let cask trains pass, which would greatly reduce the potential for accidents, including those involving hazardous chemicals.

K.2.4.9 Criticality During Accidents

Criticality is the term used to describe an uncontrolled nuclear chain reaction. U.S. Nuclear Regulatory Commission regulations at 10 CFR 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 so that even if water were to fill the cask and the cask contained unirradiated nuclear fuel (the most reactive case from the perspective of a criticality), a criticality would not occur.

Table K-29. Unit risk factors used in the transportation risk assessment (page 1 of 2).

Radionuclide	Physical form	Ingestion pathway unit risk factor (person-rem/ Ci × Ci deposited)	Inhalation pathway unit risk factor (person-rem/ Ci per people/km^2)[a]	Immersion pathway unit risk factor (person-rem/ Ci per people/km^2)	Resuspension pathway unit risk factor (person-rem/ Ci per people/km^2)	Groundshine pathway unit risk factor (person-rem/ Ci per people/km^2)
Ac-227 plus progeny	Particulates	2.12E+6	6.34E+0	3.75E-6	2.76E+1	2.21E-1
Am-241	Particulates	3.50E+5	2.98E+0	1.45E-7	1.36E+1	1.98E-2
Am-242m plus progeny	Particulates	3.33E+5	2.63E+0	1.37E-7	1.19E+1	1.46E-2
Am-243 plus progeny	Particulates	3.51E+5	2.92E+0	1.90E-6	1.33E+1	1.77E-1
Be-10	Particulates	1.92E+3	2.50E-3	2.97E-8	1.14E-2	3.00E-3
C-14	Inert gas	1.01E+3	3.91E-6	4.98E-9	0.00E+0	0.00E+0
Cd-113m	Particulates	4.02E+4	2.21E-3	1.95E-8	9.37E-3	6.33E-4
Ce-144 plus progeny	Particulates	9.19E+3	2.55E-3	7.39E-7	5.09E-3	7.00E-3
Cf-252	Particulates	1.57E+5	1.42E+0	7.85E-10	4.69E+0	5.21E-5
Cl-36	Cesium	1.63E+3	5.18E-4	3.57E-8	2.37E-3	9.85E-3
Cm-242	Particulates	2.10E+4	3.69E-1	8.67E-10	5.18E-1	1.74E-5
Cm-243	Particulates	2.62E+5	2.21E+0	1.14E-6	9.73E+0	6.35E-2
Cm-244	Particulates	2.10E+5	1.92E+0	7.33E-10	8.28E+0	2.76E-4
Cm-245	Particulates	3.67E+5	2.98E+0	7.56E-7	1.36E+1	7.06E-2
Cm-246	Particulates	3.67E+5	2.98E+0	6.69E-10	1.36E+1	5.04E-4
Cm-247 plus progeny	Particulates	3.33E+5	2.76E+0	3.20E-6	1.26E+1	2.83E-1
Cm-248	Particulates	1.35E+6	1.07E+1	5.08E-10	4.86E+1	3.88E-4
Co-58	Particulates	1.29E+3	1.49E-4	9.60E-6	1.10E-4	1.09E-2
Co-60	Particulates	5.95E+3	2.21E-3	2.56E-5	8.45E-3	3.97E-1
Co-60	Crud	5.95E+3	2.21E-3	2.56E-5	8.45E-3	3.97E-1
Cs-134	Cesium	3.32E+4	4.68E-4	1.52E-5	1.44E-3	1.21E-1
Cs-135	Cesium	3.50E+3	4.90E-5	2.05E-9	2.24E-4	2.37E-5
Cs-137 plus progeny	Cesium	2.27E+4	3.26E-4	5.50E-6	1.44E-3	3.04E-1
Eu-154	Particulates	3.50E+3	3.76E-3	1.24E-5	1.54E-2	3.05E-1
Eu-155	Particulates	5.60E+2	4.90E-4	4.63E-7	1.85E-3	8.80E-3
Fe-55	Particulates	5.77E+2	2.71E-5	0.00E+0	8.99E-5	0.00E+0
Fe-59	Particulates	3.15E+3	2.63E-4	1.21E-5	1.30E-4	8.21E-3
H-3	Inert gas	3.15E+1	1.71E-5	0.00E+0	0.00E+0	0.00E+0
I-129	Cesium	1.92E+5	2.55E-3	6.11E-8	1.17E-2	1.72E-2
Kr-85	Inert gas	0.00E+0	0.00E+0	4.60E-7	0.00E+0	0.00E+0
Mn-54	Particulates	1.24E+3	1.07E-4	8.26E-6	2.24E-4	3.28E-2
Nb-93m	Particulates	2.10E+2	3.63E-5	6.57E-10	1.54E-4	2.44E-4
Nb-94	Particulates	2.97E+3	7.81E-4	1.55E-5	3.57E-3	1.31E+0
Nb-95	Particulates	1.01E+3	1.07E-4	7.51E-6	4.27E-5	4.22E-3
Ni-59	Particulates	1.10E+2	9.24E-6	0.00E+0	4.22E-5	0.00E+0
Ni-63	Particulates	2.62E+2	3.42E-5	0.00E+0	1.54E-4	0.00E+0

Table K-29. Unit risk factors used in the transportation risk assessment (page 2 of 2).

Radionuclide	Physical form	Ingestion pathway unit risk factor (person-rem/ Ci × Ci deposited)	Inhalation pathway unit risk factor (person-rem/ Ci per people/km^2)[a]	Immersion pathway unit risk factor (person-rem/ Ci per people/km^2)	Resuspension pathway unit risk factor (person-rem/ Ci per people/km^2)	Groundshine pathway unit risk factor (person-rem/ Ci per people/km^2)
Np-237 plus progeny	Particulates	1.94E+5	1.63E+0	2.04E-6	7.46E+0	1.86E-1
Pa-231	Particulates	1.24E+6	2.42E+0	3.38E-7	1.10E+1	3.33E-2
Pb-210 plus progeny	Particulates	3.31E+6	3.19E-1	6.52E-8	1.39E+0	1.79E-2
Pd-107	Particulates	6.47E+1	4.19E-5	0.00E+0	1.91E-4	0.00E+0
Pm-147	Particulates	4.55E+2	3.48E-4	1.87E-9	1.15E-3	2.77E-6
Pu-238	Particulates	4.02E+5	1.14E+0	7.56E-10	5.13E+0	4.63E-4
Pu-239	Particulates	4.37E+5	1.14E+0	7.51E-10	5.19E+0	2.50E-4
Pu-240	Particulates	4.37E+5	1.14E+0	7.39E-10	5.19E+0	5.27E-4
Pu-241	Particulates	8.40E+3	1.21E-2	1.37E-11	5.15E-2	6.40E-7
Pu-242	Particulates	4.21E-5	1.07E+0	6.28E-10	4.86E+0	4.37E-4
Ra-226 plus progeny	Particulates	4.90E+5	2.52E-1	1.80E-5	1.15E+0	1.47E+0
Ra-228 plus progeny	Particulates	1.21E+6	1.86E-1	9.66E-6	7.21E-1	1.74E-1
Rh-102	Particulates	4.55E+3	1.21E-3	2.09E-5	4.09E-3	2.16E-1
Ru-106 plus progeny	Ruthenium	1.22E+4	2.00E-3	2.28E-6	4.56E-3	1.62E-2
Sb-125 plus progeny	Particulates	2.27E+3	3.96E-4	4.04E-6	1.32E-3	4.25E-2
Se-79	Particulates	5.07E+3	7.81E-5	8.49E-10	3.57E-4	1.45E-5
Sm-151	Particulates	1.71E+2	2.84E-4	5.32E-12	1.28E-3	2.63E-6
Sn-126 plus progeny	Particulates	8.87E+3	2.02E-3	1.94E-5	9.20E-3	1.73E+0
Sr-90 plus progeny	Particulates	5.37E+4	2.67E-3	1.92E-7	1.18E-2	6.07E-2
Tc-99	Particulates	1.12E+3	2.84E-4	6.17E-9	1.30E-3	5.69E-5
Th-228 plus progeny	Particulates	2.51E+5	3.07E+0	1.65E-5	9.18E+0	1.11E-1
Th-229 plus progeny	Particulates	1.07E+6	6.11E+0	3.01E-6	2.79E+1	3.05E-1
Th-230	Particulates	3.67E+5	9.95E-1	3.21E-9	4.54E+0	5.61E-4
Th-232	Particulates	4.02E+5	1.78E+0	1.57E-9	8.11E+0	3.99E-4
U-232	Particulates	5.77E+5	2.63E+0	2.54E-9	1.18E+1	5.76E-4
U-233	Particulates	8.92E+4	6.82E-1	3.05E-9	3.11E+0	5.28E-4
U-234	Particulates	8.57E+4	6.68E-1	1.32E-9	3.05E+0	5.14E-4
U-235 plus progeny	Particulates	8.28E+4	6.05E-1	1.50E-6	2.76E+0	1.37E-1
U-236	Particulates	8.22E+4	6.18E-1	8.32E-10	2.82E+0	4.43E-4
U-238 plus progeny	Particulates	8.47E+4	5.68E-1	3.49E-7	2.59E+0	1.04E-1
Zr-93	Particulates	1.92E+3	7.10E-4	0.00E+0	3.24E-3	0.00E+0

a. km^2 = square kilometer; to convert person-rem/Ci per people/square kilometer to person-rem/Ci per people/square mile, multiply by 0.386102

K.2.4.10 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, DOE analyzed the consequences of an accident in which a large commercial aircraft or a military aircraft is hypothesized to directly hit a cask (DIRS 155970-DOE 2002, Section J.3.3.1). The analysis showed that the heavy shield wall of a cask could not be breached by the penetrating force of the aircraft's center shaft. 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 the integrity of the cask.

System malfunctions or material failures that could result in either an accidental release of ordnance or release of a practice weapon were discussed in 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). The Special Nevada Report (DIRS 153277-SAIC 1991,all) states that the probability of dropped ordnance resulting 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 dropped ordnance incident. Less than one accidentally dropped ordnance incident is estimated per year for all flight operations over the Nellis Air Force Range (now called the Nevada Test and Training Range) and Naval Air Station Fallon. All of these analyses are incorporated in the Rail Alignment EIS by reference. Spent nuclear fuel transportation would not affect the risk from dropped ordnance or aircraft crashes. The Rail Alignment EIS 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 so extremely low that it is not reasonably foreseeable. Accordingly, DOE believes there would be no need for associated mitigation measures and no impacts on military operations.

K.2.4.11 Baltimore Tunnel Fire

On July 18, 2001, a freight train carrying hazardous (non-nuclear) materials derailed and caught fire while passing through the Howard Street railroad tunnel in downtown Baltimore, Maryland. The possible impacts of this fire were evaluated by the Nuclear Regulatory Commission 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 the three transportation casks, the HOLTEC Model No. HI-STAR 100, the TransNuclear Model No. TN-68, and the Nuclear Assurance Corporation (NAC) Legal Weight Truck (LWT), to the conditions that existed during the fire. This study concluded that larger transportation packages resembling 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 is due to their sizable thermal inertia and design specifications in compliance with currently imposed regulatory requirements.

For the TN-68 and the NAC LWT, 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 to occur for these conditions, any release that could occur would be very small due to a number of factors. These include (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 radiological consequences of the package responses to the Baltimore tunnel fire were also evaluated. The analysis indicates 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 NAC LWT could experience some decrease in gamma shielding due to slump in the lead as a consequence of this fire scenario, but a conservative analysis shows that the regulatory dose rate limits would not be exceeded.

The results of this evaluation also 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 NAC LWT) 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 within the fuel rods.

There would be no release from the HI-STAR 100, because the inner welded canister remains leak tight. While a release is unlikely, the potential releases calculated for the TN-68 rail cask and the NAC LWT truck cask indicate that any release of crud from either cask would be very small—less than an A_2 quantity. The release of an A_2 quantity is approximately equivalent to a radiation dose of 5 rem.

The Nuclear Regulatory Commission also evaluated the response of the NAC LWT 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 tank 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 NAC LWT 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 (TFE) or Viton seals, making it possible for a small release to occur due to crud that might spall off the surfaces of the fuel rods. However, any release is expected to be very small due to a number of factors. These include (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 consequently not be available for release.

The radiological consequences of the package response to the Caldecott Tunnel fire were also evaluated. 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 NAC LWT 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 within the fuel rods. The potential release calculated for the NAC LWT cask in this scenario indicates that any release of crud from the cask would be very small—less than an A_2 quantity. The release of an A_2 quantity is approximately equivalent to a radiation dose of 5 rem.

K.2.5 MAXIMUM REASONABLY FORESEEABLE TRANSPORTATION ACCIDENTS

In addition to analyzing the radiological risks of transporting spent nuclear fuel and high-level radioactive waste, the consequences of severe transportation accidents were assessed. DOE evaluated the consequences of severe transportation accidents to determine the consequences of the maximum reasonably foreseeable accident in the context of transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain. According to DOE guidance, accidents that have a frequency of less than 1×10^{-7} rarely need to be examined because they are not reasonably foreseeable (DIRS 172283-DOE 2002, p. 9). The maximum reasonably foreseeable accident analyzed in this Rail Alignment EIS has a frequency greater than 1×10^{-7} per year.

In the Rail Alignment EIS, DOE assumed that the maximum reasonably foreseeable accident could occur anywhere along the rail alignment. There are no urban areas along the Caliente rail alignment or the Mina rail alignment. However, there are suburban areas and rural areas. Suburban areas are defined as areas with a population density between 54 and 1,284 people per square kilometer (139 and 3,326 people per square mile). Rural areas were defined as areas with a population density less than 54 people per square kilometer (139 people per square mile). For the Caliente rail alignment, using alignment-specific 2000 Census population data escalated to the year 2067, the average population density in suburban areas along the rail alignment ranged from 223 to 226 people per square kilometer (577 to 586 people per square mile) (see Table K-30). The average population density in rural areas, escalated to the year 2067, ranged from 0.346 to 0.585 people per square kilometer (0.896 to 1.51 people per square mile) (see Table K-30). For the Mina rail alignment, using alignment-specific 2000 census population data escalated to the year 2067, the average population density in suburban areas along the rail alignment ranged from 542 to 589 people per square kilometer (1,400 to 1,530 people per square mile) (see Table K-31). The average population density in rural areas, escalated to the year 2067, ranged from 3.94 to 4.33 people per square kilometer (10.2 to 11.2 people per square mile) (see Table K-31). Radiation doses were estimated out to 80 kilometers (50 miles) using these population densities.

DOE used the following assumptions to estimate the consequences of the maximum reasonably foreseeable accident (DIRS 157144-Jason Technologies 2001, Section 5.3.3.3):

- A release height of the plume of 10 meters (33 feet) for both 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 yields 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 per year (367,000 cubic feet per year). This breathing rate was estimated from data contained in ICRP Publication 23 (DIRS 101074-ICRP 1975, page 346).
- All material released is assumed to be aerosolized and respirable (DIRS 157144-Jason Technologies 2001, p. 177). The deposition velocity for respirable material was 0.01 meter per second (0.033 foot per second).
- 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.
- Consequences were determined using low wind speeds and stable atmospheric conditions (a wind speed of 0.89 meter per second [2.9 feet per second] and Class F stability). The severe accident scenario calculation methodology does not include a probabilistic component that includes the atmospheric stability, therefore stable conditions were assumed. Atmospheric conditions affect the

Table K-30. Projected population densities along the Caliente rail alignment in 2067.

Alignment	Escalated urban population density (people/mi^2)[a,b]	Escalated suburban population density (people/mi^2)	Escalated rural population density (people/mi^2)
Highest population	--	579	1.51
Shortest distance	--	577	1.37
Longest distance	--	586	0.915
Lowest population	--	--	0.896

a. mi^2 = square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.
b. Note that there are no urban areas along the rail alignments.

Table K-31. Projected population densities along the Mina rail alignment in 2067.

Alignment	Escalated urban population density (people/mi^2)[a,b]	Escalated suburban population density (people/mi^2)	Escalated rural population density (people/mi^2)
Highest population	--	1,420	10.8
Shortest distance	--	1,530	11.0
Longest distance	--	1,400	11.2
Lowest population	--	1,530	10.2

a. mi^2 = square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.
b. Note that there are no urban areas along the rail alignments.

- dispersion of radionuclides that could be released from a severe accident. The atmospheric concentrations estimated from these atmospheric conditions would be exceeded only 5 percent of the time. Using these atmospheric conditions instead of neutral atmospheric conditions and moderate wind speeds reduces the probability associated with an accident scenario and increases the consequences associated with an accident scenario.
- Consequences were determined for a single rail cask containing 21 pressurized-water-reactor spent nuclear fuel assemblies.
- The spent nuclear fuel assembly has a burnup of 60 MWd/MTHM, an enrichment of 4 percent, and a decay time of 10 years (DIRS 169061-BSC 2004, all). The radionuclide inventory for a single spent nuclear fuel assembly is listed in Table K-13.

Impacts of Severe Accidents DOE has assumed for the purposes of estimating the radiological consequences of severe accidents and sabotage events that there would be no interdiction or cleanup for 1 year after the accident or sabotage event. However, DOE anticipates that for any significant release that emergency response, interdiction, and cleanup actions would be initiated. Therefore, the assumption that no interdiction or cleanup would take place for 1 year after a severe accident or sabotage event would tend to result in overestimation of the impacts of severe accidents and sabotage events.

DOE estimated radiation doses using the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all) and determined them 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). Radiation doses were estimated using the ICRP inhalation dose coefficients (DIRS 172935-ICRP 2001, all) and the EPA groundshine and immersion dose coefficients (DIRS 175544-EPA 2002, all). These dose coefficients are based on the recommendations by the International Commission on Radiological

Protection in ICRP Publication 60 (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from ICRP Publication 72 (DIRS 152446-ICRP 1996, all). Table K-32 lists these dose coefficients. The dose coefficients include radioactive progeny (DIRS 176975-BMI 2006, Table 2). The lung absorption type and the value for the fractional absorption from the small intestine (f_1) for each radionuclide are listed in DIRS 176975-BMI 2006, Table 4.

Table K-32. RISKIND dose coefficients (page 1 of 2).

Radionuclide	Groundshine pathway dose conversion factor (rem-m^2/Ci-s)[a]	Immersion pathway dose conversion factor (rem-m^3/Ci-s)[b]	Inhalation pathway dose conversion factor (rem/Ci)	Ingestion pathway dose conversion factor (rem/Ci)
Ac-227 plus progeny	1.73E-03	6.45E-02	3.30E+08	4.47E+06
Am-241	8.62E-05	2.50E-03	1.55E+08	7.40E+05
Am-242m plus progeny	7.71E-05	2.80E-03	1.37E+08	7.04E+05
Am-243 plus progeny	7.47E-04	3.26E-02	1.52E+08	7.43E+05
Be-10	1.26E-05	5.11E-04	1.30E+05	4.07E+03
C-14	4.74E-08	9.62E-06	2.29E+01	2.15E+03
Cd-113m	6.55E-06	3.35E-04	1.15E+05	8.51E+04
Ce-144 plus progeny	6.72E-04	1.27E-02	1.33E+05	1.94E+04
Cf-252	1.94E-06	1.35E-05	7.40E+07	3.33E+05
Cl-36	4.14E-05	6.14E-04	2.70E+04	3.44E+03
Cm-242	2.60E-06	1.49E-05	1.92E+07	4.44E+04
Cm-243	4.37E-04	1.96E-02	1.15E+08	5.55E+05
Cm-244	2.38E-06	1.26E-05	9.99E+07	4.44E+05
Cm-245	2.98E-04	1.30E-02	1.55E+08	7.77E+05
Cm-246	2.13E-06	1.15E-05	1.55E+08	7.77E+05
Cm-247 plus progeny	1.19E-03	5.50E-02	1.44E+08	7.03E+05
Cm-248	1.63E-06	8.73E-06	5.55E+08	2.85E+06
Co-58	3.42E-03	1.65E-01	7.77E+03	2.74E+03
Co-60	8.51E-03	4.40E-01	1.15E+05	1.26E+04
Co-60 (crud)	8.51E-03	4.40E-01	1.15E+05	1.26E+04
Cs-134	5.48E-03	2.62E-01	2.44E+04	7.03E+04
Cs-135	9.95E-08	3.52E-05	2.55E+03	7.40E+03
Cs-137 plus progeny	2.03E-03	9.45E-02	1.70E+04	4.81E+04
Eu-154	4.33E-03	2.13E-01	1.96E+05	7.40E+03
Eu-155	1.98E-04	7.96E-03	2.55E+04	1.18E+03
Fe-55	0.00E+00	0.00E+00	1.41E+03	1.22E+03
Fe-55 (crud)	0.00E+00	0.00E+00	1.41E+03	1.22E+03
Fe-59	4.07E-03	2.08E-01	1.37E+04	6.66E+03
H-3	0.00E+00	0.00E+00	9.99E+01	6.66E+01
I-129	7.25E-05	1.05E-03	1.33E+05	4.07E+05
Kr-85	3.89E-05	8.88E-04	0.00E+00	0.00E+00
Mn-54	2.92E-03	1.42E-01	5.55E+03	2.63E+03
Nb-93m	2.52E-06	1.13E-05	1.89E+03	4.44E+02

Table K-32. RISKIND dose coefficients (page 2 of 2).

Radionuclide	Groundshine pathway dose conversion factor (rem-m^2/Ci-s)[a]	Immersion pathway dose conversion factor (rem-m^3/Ci-s)[b]	Inhalation pathway dose conversion factor (rem/Ci)	Ingestion pathway dose conversion factor (rem/Ci)
Nb-94	5.51E-03	2.66E-01	4.07E+04	6.29E+03
Nb-95	2.69E-03	1.29E-01	5.55E+03	2.15E+03
Ni-59	0.00E+00	0.00E+00	4.81E+02	2.33E+02
Ni-63	0.00E+00	0.00E+00	1.78E+03	5.55E+02
Np-237 plus progeny	7.81E-04	3.50E-02	8.51E+07	4.10E+05
Pa-231	1.40E-04	5.81E-03	1.26E+08	2.63E+06
Pb-210 plus progeny	1.38E-04	1.12E-03	1.66E+07	7.00E+06
Pd-107	0.00E+00	0.00E+00	2.18E+03	1.37E+02
Pm-147	1.04E-07	3.21E-05	1.81E+04	9.62E+02
Pu-238	2.32E-06	1.30E-05	5.92E+07	8.51E+05
Pu-239	1.05E-06	1.29E-05	5.92E+07	9.25E+05
Pu-240	2.22E-06	1.27E-05	5.92E+07	9.25E+05
Pu-241	6.36E-09	2.35E-07	6.29E+05	1.78E+04
Pu-242	1.84E-06	1.08E-05	5.55E+07	8.88E+05
Ra-226 plus progeny	6.24E-03	3.10E-01	1.31E+07	1.04E+06
Ra-228 plus progeny	3.47E-03	1.66E-01	9.68E+06	2.55E+06
Rh-102	7.47E-03	3.59E-01	6.29E+04	9.62E+03
Ru-106 plus progeny	1.28E-03	3.92E-02	1.04E+05	2.59E+04
Sb-125 plus progeny	1.53E-03	6.95E-02	2.06E+04	4.80E+03
Se-79	6.11E-08	1.46E-05	4.07E+03	1.07E+04
Sm-151	1.31E-08	9.14E-08	1.48E+04	3.63E+02
Sn-126 plus progeny	7.28E-03	3.33E-01	1.05E+05	1.88E+04
Sr-90 plus progeny	4.13E-04	3.30E-03	1.39E+05	1.14E+05
Tc-99	2.40E-07	1.06E-04	1.48E+04	2.37E+03
Th-228 plus progeny	5.32E-03	2.83E-01	1.60E+08	5.30E+05
Th-229 plus progeny	1.28E-03	5.16E-02	3.18E+08	2.27E+06
Th-230	2.36E-06	5.51E-05	5.18E+07	7.77E+05
Th-232	1.68E-06	2.69E-05	9.25E+07	8.51E+05
U-232	2.99E-06	4.37E-05	1.37E+08	1.22E+06
U-233	2.22E-06	5.25E-05	3.55E+07	1.89E+05
U-234	2.17E-06	2.27E-05	3.48E+07	1.81E+05
U-235 plus progeny	5.76E-04	2.57E-02	3.15E+07	1.75E+05
U-236	1.86E-06	1.43E-05	3.22E+07	1.74E+05
U-238 plus progeny	4.50E-04	6.63E-03	2.96E+07	1.79E+05
Zr-93	0.00E+00	0.00E+00	3.70E+04	4.07E+03

a. m^2 = square meter; to convert rem-square meter/Ci-s to rem-square foot/Ci-s, multiply by 10.763910.
b. m^3 = cubic meter; to convert rem-cubic meter/Ci-s to rem-cubic foot/Ci-s, multiply by 35.314667.

The evaluation of severe transportation accidents analysis was based on a review of the 20 rail accident severity categories identified in *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, p. 7-76) that result in releases of radioactive material from a rail cask. 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 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 (many hours), high-temperature, engulfing fire. Case 18, Case 17, and Case 16 are accidents that would also involve very long-duration fires, failures of cask seals, and punctures of cask walls. However, these accidents would be progressively less severe in terms of impact speeds. The impact speeds range from 90 to 120 miles per hour for Case 18, 60 to 90 miles per hour for Case 17, and 30 to 60 miles per hour for Case 16.
- Cases 15, 12, 9, and 6: Case 15 is a high-speed (more than 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 (many hours), high-temperature, engulfing fire. Case 12, Case 9, and Case 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 90 to 120 miles per hour for Case 12, 60 to 90 miles per hour for Case 9, and 30 to 60 miles per hour for Case 6.
- Cases 14, 11, 8, and 5: Case 14 is a high-speed (more than 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. Case 11, Case 8, and Case 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 90 to 120 miles per hour for Case 11, 60 to 90 miles per hour for Case 8, and 30 to 60 miles per hour for Case 5.
- Cases 13, 10, 7, and 4: Case 13 is a high-speed (more than 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 ½ hour up to a few hours. Case 10, Case 7, and Case 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 90 to 120 miles per hour for Case 10, 60 to 90 miles per hour for Case 7, and 30 to 60 miles per hour for Case 4.
- Cases 3, 2, and 1: Case 3 is a high-speed (more than 120 miles per hour) impact into a hard surface such as granite severe enough to cause failure of cask seals—no fire. Case 2 and Case 1 are accidents that would also not involve fire but would have progressively lower impact speeds - 90 to 120 miles per hour for Case 2 and 60 to 90 miles per hour for Case 1.

The *Reexamination of Spent Fuel Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7-73 and 7-76) also evaluated Case 21, which is an accident that does not result in a release of radioactive material from a rail cask. Each of the 20 accident cases listed above has an associated conditional probability of occurrence (DIRS 152476-Sprung et al. 2000, p. 7-76). These conditional probabilities were combined with the distances along the Caliente and Mina rail alignments and the accident rates discussed in Section K.2.5 to estimate the frequency of occurrence for each accident case. These frequencies are listed in Table K-33.

Cases 1, 4, and 20 have frequencies greater than 1×10^{-7} per year. Case 20 is estimated to have the highest consequences of these three accident cases (DIRS 155970-DOE 2002, Table J-22).

Therefore, Case 20 is considered to be the maximum reasonably foreseeable transportation accident. Table K-34 lists the release fractions and conditional probabilities for this accident (DIRS 152476-Sprung et al. 2000, p. 7-76).

Table K-33. Annual frequencies for accident severity cases.

Accident severity case	Annual frequency (accidents per year)
1	1×10^{-7}
2	$7 \times 10^{-9} – 8 \times 10^{-9}$
3	6×10^{-11}
4	4×10^{-7}
5	1×10^{-8}
6	$1 \times 10^{-9} – 2 \times 10^{-9}$
7	$8 \times 10^{-10} – 9 \times 10^{-10}$
8	$2 \times 10^{-11} – 3 \times 10^{-11}$
9	3×10^{-12}
10	6×10^{-11}
11	2×10^{-12}
12	2×10^{-13}
13	5×10^{-13}
14	1×10^{-14}
15	2×10^{-15}
16	$5 \times 10^{-12} – 6 \times 10^{-12}$
17	3×10^{-15}
18	2×10^{-16}
19	2×10^{-18}
20	$7 \times 10^{-7} – 6 \times 10^{-7}$

K.2.6 TRANSPORTATION SABOTAGE

In the Rail Alignment EIS, DOE assumed that a sabotage event could occur anywhere along the Caliente or Mina rail alignment. Radiation doses have been estimated out to 80 kilometers (50 miles) from each rail alignment using the population densities listed in Tables K-30 and K-31.

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 per year (367,000 cubic feet per year). This breathing rate was estimated from data contained in ICRP 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.
- Because it is not possible to estimate the specific atmospheric conditions that would exist during a sabotage event, consequences were determined using moderate wind speeds and neutral atmospheric conditions (a wind speed of 4.47 meters per second [15 feet per second] and Class D stability).
- The release of both respirable and nonrespirable material was evaluated. The deposition velocity for respirable material was 0.01 meter per second (0.033 feet per second). The deposition velocity for nonrespirable material was 0.1 meter per second (0.33 feet per second).
- It is expected that in a sabotage event, there would be an initial explosive release involving releases of radioactive material at varying release heights. For 4 percent of the release, a release height of 1 meter (3.3 feet) was estimated; for 16 percent of the release, a release height of 16 meters (52 feet) was estimated; for 25 percent of the release, a release height of 32 meters (100 feet) was estimated; for 35 percent of the release, a release height of 48 meters (160 feet) was estimated; and for 20 percent of the release, a release height of 64 meters (210 feet) was estimated.

Table K-34. Conditional probabilities and release fractions for severe accident cases.[a]

Severe accident case	Conditional probability	Release fraction				
		Inert gas	Cesium	Ruthenium	Particulates	Crud
20	4.91×10^{-5}	0.84	1.7×10^{-5}	2.5×10^{-7}	2.5×10^{-7}	9.4×10^{-3}

a. Source: DIRS 152476-Sprung et al. 2000, p. 7-76.

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 the Rail Alignment EIS, 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. The radionuclide inventory for a single spent nuclear fuel assembly in this cask is listed in Table K-13.

In the Yucca Mountain FEIS, DOE evaluated the consequences of sabotage events using the release fraction data contained in Luna et al. (1999) (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all; DIRS 155970-DOE 2002, Section 6.2.4.2.3). For rail casks, a sabotage event using the high-energy density device denoted HEDD1 yielded the largest radiation doses. Additional data from sabotage experiments conducted in Germany were used by DOE to update the release fractions for HEDD1 (DIRS 181279-Luna 2006, all) used to estimate the consequences of sabotage events in the Rail Alignment EIS. Table K-35 lists these release fractions.

Table K-35. Release fractions for transportation sabotage event.[a]

	Release fraction					
Material	Particulates	Ruthenium[b]	Cesium[c]	Iodine[c]	Gas	Crud
Respirable	7.19×10^{-7}	7.19×10^{-7}	7.15×10^{-6}[d]	7.15×10^{-6}[d]	4.05×10^{-4}[d]	5.17×10^{-7}
Nonrespirable	1.75×10^{-4}	1.75×10^{-4}				5.16×10^{-8}

a. Source: DIRS 181279-Luna 2006, all.
b. Ruthenium is modeled as particulate.
c. Cesium and iodine are modeled as volatiles.
d. All cesium, iodine, and gases were assumed to be respirable.

Radiation doses for the sabotage event scenario were estimated using the RISKIND computer code (DIRS 101483-Yuan et al. 1995, all). RISKIND has been verified and validated for estimating radiation doses from releases of radioactive material during transportation (DIRS 101845-Maheras and Pippen 1995, all; DIRS 102060-Biwer et al. 1997, all). Radiation doses were determined for the inhalation, groundshine, immersion, and resuspension pathways. Radiation doses were estimated using the ICRP inhalation dose coefficients (DIRS 172935-ICRP 2001, all) and the EPA groundshine and immersion dose coefficients (DIRS 175544-EPA 2002, all). These dose coefficients are based on the recommendations by the International Commission on Radiological Protection in ICRP Publication 60 (DIRS 101836-ICRP 1991, all) and incorporate the dose coefficients from ICRP Publication 72 (DIRS 152446-ICRP 1996, all). These dose coefficients are listed in Table K-32.

K.2.7 RESULTS FOR THE CALIENTE RAIL ALIGNMENT

K.2.7.1 Incident-Free Impacts

This section presents the radiological impacts of incident-free transportation for workers and members of the public. Impacts are presented for rail workers and escorts en route to the repository, for workers located at the Maintenance-of-Way Facility or Maintenance-of-Way Trackside Facility and at sidings, for workers at the Staging Yard, and for members of the public along the rail alignment and near the Staging Yard under the Proposed Action and the Shared-Use Option.

K.2.7.1.1 Workers and Members of the Public En Route to the Repository

K.2.7.1.1.1 Workers. During the shipment of spent nuclear fuel and high-level radioactive waste from the Caliente or Eccles Interchange Yard to the repository, workers would be potentially exposed to direct radiation from 9,495 shipping casks.

Table K-36 lists the collective radiation doses and impacts for these workers. Because dedicated trains would be used for transporting spent nuclear fuel and high-level radioactive waste from Caliente or Eccles to the repository and under normal circumstances there would be no en route stops between the Staging Yard and the repository, therefore there would be no radiation doses at stops for rail workers (engineers and conductors) or escorts. Because rail workers would be working in the cab of the locomotive and situated at a distance of at least 45.7 meters (150 feet) from the nearest cask, and would be shielded from radiation by the locomotive, there would be no radiation doses for these workers while en route to the repository.

The collective radiation dose for the workers is estimated to be 310 to 320 person-rem, with longer alignments having higher estimated radiation doses. The radiation doses would be the same for the Proposed Action and the Shared-Use Option. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.19 or about 1 chance in 5. For perspective, in the United States the lifetime risk of dying from cancer is about 1 in 5.

For workers who could potentially be exposed to radiation when cask trains pass by the Maintenance-of-Way Facility or Maintenance-of-Way Trackside Facility, the collective radiation dose was estimated to be 0.044 person-rem. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 2.7×10^{-5} or about 1 chance in 30,000. The impacts for these workers would be the same for the Proposed Action and the Shared-Use Option. In addition, the impacts for these workers would not depend on the length of the rail alignment.

For workers who could potentially be exposed when a train containing loaded casks passed a train containing empty casks or other materials at a siding, the collective radiation dose is estimated to be 0.0024 person-rem for the Proposed Action and 0.0051 person-rem for the Shared-Use Option. The radiation dose is higher for the Shared-Use Option because there would be increased rail traffic and therefore more opportunities for a train to be passed at a siding and more opportunities for workers to be potentially exposed. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 1.4×10^{-6} for the Proposed Action and 3.0×10^{-6} for the Shared-Use Option, corresponding to about 1 chance in 700,000 and about 1 chance in 300,000.

The total collective radiation dose for all workers potentially exposed en route to the repository is estimated to range from 310 to 320 person-rem. The radiation dose for escorts accounts for more than 99 percent of the total radiation dose to workers. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.19.

Table K-37 lists the maximally exposed individual radiation doses and impacts for all workers. The maximally exposed worker would be an escort. This worker is estimated to receive a radiation dose of 25 rem over the 50 years of operations, based on a 0.5 rem per year administrative dose limit for repository facilities (DIRS 174942-BSC 2005, Section 4.9.3.3) and a person working for up to 50 years escorting shipments. The probability of a latent cancer fatality for this worker is estimated to be 0.015 or about 1 chance in 60.

An individual worker at the Maintenance-of-Way Facility or Maintenance-of-Way Trackside Facility was estimated to receive a radiation dose of 8.8×10^{-4} rem over 50 years of operations and assuming that the worker was exposed to all loaded casks that passed the facility. The probability of a latent cancer fatality for this worker is estimated to be 5.3×10^{-7}, or about 1 chance in 1,800,000.

An individual worker at a siding passed by loaded cask trains was estimated to receive a radiation dose of 2.4×10^{-4} rem for the Proposed Action and 5.1×10^{-4} rem for the Shared-Use Option over 50 years of operations and assuming that the worker was exposed to all loaded casks that passed a siding. The

Table K-36. Incident-free collective radiation doses and latent cancer fatalities for en route workers and members of the public for the Caliente rail alignment (page 1 of 2).

		Collective radiation dose (person-rem)										
Rail alignment	Interchange location	En route rail workers[a]	En route rail workers at stops	En route escorts	En route escorts at stops	MOW[b] Facility or Trackside Facility workers	Workers located at sidings	Total en route workers	Off-link public along route	On-link public along route	Stops public along route	Total public along route
Proposed Action												
Highest population	Caliente	0.0E+0	0.0E+0	3.2E+2	0.0E+0	4.4E-2	0.0024	3.2E+2	2.1E-1	0.0E+0	0.0E+0	2.1E-1
Shortest distance	Caliente	0.0E+0	0.0E+0	3.1E+2	0.0E+0	4.4E-2	0.0024	3.1E+2	1.8E-1	0.0E+0	0.0E+0	1.8E-1
Longest distance	Eccles	0.0E+0	0.0E+0	3.2E+2	0.0E+0	4.4E-2	0.0024	3.2E+2	1.1E-1	0.0E+0	0.0E+0	1.1E-1
Lowest population	Eccles	0.0E+0	0.0E+0	3.1E+2	0.0E+0	4.4E-2	0.0024	3.1E+2	8.7E-2	0.0E+0	0.0E+0	8.7E-2
Shared-Use Option												
Highest population	Caliente	0.0E+0	0.0E+0	3.2E+2	0.0E+0	4.4E-2	0.0051	3.2E+2	2.1E-1	0.0E+0	0.0E+0	2.1E-1
Shortest distance	Caliente	0.0E+0	0.0E+0	3.1E+2	0.0E+0	4.4E-2	0.0051	3.1E+2	1.8E-1	0.0E+0	0.0E+0	1.8E-1
Longest distance	Eccles	0.0E+0	0.0E+0	3.2E+2	0.0E+0	4.4E-2	0.0051	3.2E+2	1.1E-1	0.0E+0	0.0E+0	1.1E-1
Lowest population	Eccles	0.0E+0	0.0E+0	3.1E+2	0.0E+0	4.4E-2	0.0051	3.1E+2	8.7E-2	0.0E+0	0.0E+0	8.7E-2

Table K-36. Incident-free collective radiation doses and latent cancer fatalities for en route workers and members of the public for the Caliente rail alignment (page 2 of 2).

		Latent cancer fatalities										
Rail alignment	Interchange location	En route rail workers[a]	En route rail workers at stops	En route escorts	En route escorts at stops	MOW[b] Facility or Trackside Facility workers	Workers located at sidings	Total en route workers	Off-link public along route	On-link public along route	Stops public along route	Total public along route
Proposed Action												
Highest population	Caliente	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	1.4E-6	1.9E-1	1.3E-4	0.0E+0	0.0E+0	1.3E-4
Shortest distance	Caliente	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	1.4E-6	1.9E-1	1.1E-4	0.0E+0	0.0E+0	1.1E-4
Longest distance	Eccles	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	1.4E-6	1.9E-1	6.4E-5	0.0E+0	0.0E+0	6.4E-5
Lowest population	Eccles	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	1.4E-6	1.9E-1	5.2E-5	0.0E+0	0.0E+0	5.2E-5
Shared-Use Option												
Highest population	Caliente	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	3.0E-6	1.9E-1	1.3E-4	0.0E+0	0.0E+0	1.3E-4
Shortest distance	Caliente	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	3.0E-6	1.9E-1	1.1E-4	0.0E+0	0.0E+0	1.1E-4
Longest distance	Eccles	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	3.0E-6	1.9E-1	6.4E-5	0.0E+0	0.0E+0	6.4E-5
Lowest population	Eccles	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.7E-5	3.0E-6	1.9E-1	5.2E-5	0.0E+0	0.0E+0	5.2E-5

a. Rail workers are engineers and conductors.

b. MOW = Maintenance-of-Way.

Table K-37. Incident-free maximally exposed individual radiation doses and latent cancer fatalities for en route workers and members of the public for the Caliente rail alignment.

Severe accident case	Radiation dose (rem)	Latent cancer fatalities
Proposed Action		
Workers		
Escort (1 year of operations)	0.50	0.00030
Escort (50 years of operations)	25	0.015
Worker at Maintenance-of-Way Facility or Trackside Facility	8.8E-04	5.3E-07
Worker at siding	2.4E-4	1.4E-7
Members of the public		
Resident near rail line (18 meters [60 feet])	7.8E-3	4.7E-6
Shared-Use Option		
Workers		
Escort (1 year of operations)	0.50	0.00030
Escort (50 years of operations)	25	0.015
Worker at Maintenance-of-Way Facility or Trackside Facility	8.8E-04	5.3E-07
Worker at siding	5.1E-4	3.0E-7
Members of the public		
Resident near rail line (18 meters [60 feet])	7.8E-3	4.7E-6

probability of a latent cancer fatality for this worker is estimated to be 1.4×10^{-7} (1 chance in 7,100,000) for the Proposed Action and 3.0×10^{-7} (1 chance in 3,300,000) for the Shared-Use Option.

K.2.7.1.1.2 Members of the Public. During the shipment of spent nuclear fuel and high-level radioactive waste from the Caliente or Eccles Interchange Yard to the repository, members of the public along the rail alignment could be potentially exposed to direct radiation from 9,495 shipping casks.

Table K-36 lists the collective radiation doses and impacts for members of the public. Because dedicated trains would be used for transporting spent nuclear fuel and high-level radioactive waste from Caliente or Eccles to the repository and there would be no en route stops under normal circumstances, there would be no radiation doses at stops for members of the public. In addition, because two trains could not share the single railroad track simultaneously, there would be no on-link radiation doses for members of the public.

The collective radiation dose for members of the public potentially exposed along the rail alignment (off-link) is estimated to range from 0.087 to 0.21 person-rem, with rail alignments having higher populations also having higher estimated radiation doses. These radiation doses are based on the population in the year 2000 escalated to the year 2067. The radiation doses for members of the public would be the same for the Proposed Action and the Shared-Use Option. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would range from 5.2×10^{-5} to 1.3×10^{-4}, or about 1 chance in 19,000 to about 1 chance in 7,000. For perspective, in the United States the lifetime risk of dying from cancer is about 1 in 5.

Table K-37 lists the maximally exposed individual radiation doses and impacts for members of the public. The maximally exposed individual would be a resident who lives 18 meters (60 feet) from the rail line. This individual would be exposed to each of 9,495 shipping casks as they passed by en route to the repository. The radiation dose for this individual is estimated to be 0.0078 rem over the course of a shipping campaign of 50 years. The probability of a latent cancer fatality for this individual is estimated to be 4.7×10^{-6} or 1 chance in 200,000.

K.2.7.1.2 Workers and Members of the Public at the Staging Yard

K.2.7.1.2.1 Workers. When shipping casks arrive at the Staging Yard, the railcars containing the shipping cask would be removed from the train, an inspection conducted, and the railcar transferred to the train to be transported to the repository. The escorts that had accompanied the shipping cask from its point of origin would also be present during this inspection. These railcar-handling, escort, and inspection workers would be potentially exposed to direct radiation from 9,495 shipping casks over 50 years of transporting spent nuclear fuel and high-level radioactive waste to the repository. Noninvolved workers at the Staging Yard would also be potentially exposed to direct radiation from the casks.

Table K-38 lists the collective radiation doses and impacts for these workers. Because operations at the three potential Staging Yard locations at Caliente-Indian Cove, Caliente-Upland, and Eccles-North would be similar, the radiation doses to workers at each Staging Yard would be the same. In addition, the radiation dose to workers at the Staging Yard would be the same for the Proposed Action and the Shared-Use Option because the number of shipping casks handled at the Staging Yard would be the same for the Proposed Action and the Shared-Use Option.

The collective radiation dose for involved workers at the Staging Yard is estimated to be 240 person-rem. These radiation doses are in large part dependent on the time that a cask spent in the Staging Yard, which is estimated to be 2 hours, and on the close proximity of the inspector to the cask, which is estimated to be 1 meter (3.3 feet). In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.14.

Table K-38. Incident-free collective radiation doses and latent cancer fatalities at the Caliente and Eccles Staging Yards for workers and members of the public.

	Collective radiation dose (person-rem)			
Staging Yard location	Involved workers at Staging Yard	Noninvolved workers at Staging Yard	Total workers at Staging Yard	Public near Staging Yard
Proposed Action and Shared-Use Option				
Caliente-Indian Cove	2.4E+2	1.2E+1	2.5E+2	2.6E-2
Caliente-Upland	2.4E+2	1.2E+1	2.5E+2	6.4E-3
Eccles-North	2.4E+2	1.2E+1	2.5E+2	3.9E-3
	Latent cancer fatalities			
Staging Yard location	Involved workers at Staging Yard	Noninvolved workers at Staging Yard	Total workers at Staging Yard	Public near Staging Yard
Proposed Action and Shared-Use Option				
Caliente-Indian Cove	1.4E-1	7.4E-3	1.5E-1	1.6E-5
Caliente-Upland	1.4E-1	7.4E-3	1.5E-1	3.9E-6
Eccles-North	1.4E-1	7.4E-3	1.5E-1	2.4E-6

The collective radiation dose for noninvolved workers at the Staging Yard is estimated to be 12 person-rem. These radiation doses are in large part dependent on the time that a noninvolved worker is assumed to spend in the Staging Yard, which is estimated to be 2 hours, at an estimated distance of 100 meters (330 feet) from the casks. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.0074.

The total collective radiation dose for involved and noninvolved workers at the Staging Yard is estimated to be 250 person-rem. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.15.

Table K-39 lists the maximally exposed individual radiation doses and impacts for workers at each potential Staging Yard location. The maximally exposed worker would be an inspector, rail worker, or escort. This individual is estimated to receive a radiation dose of 25 rem over the 50 years of operations, based on a 0.5 rem per year administrative dose limit at repository facilities (DIRS 174942-BSC 2005, Section 4.9.3.3) for a person working for up to 50 years at the Staging Yard. The probability of a latent cancer fatality for this worker is estimated to be 0.015 or about 1 chance in 60.

Table K-39. Incident-free maximally exposed individual radiation doses and latent cancer fatalities at the Caliente and Eccles Staging Yards for workers and members of the public.

Proposed Action and Shared-Use Option	Radiation dose (rem)	Latent cancer fatalities
Workers		
Escort, rail worker, or inspector (1 year of operations)	0.50	0.00030
Escort, rail worker, or inspector (50 years of operations)	25	0.015
Members of the public – resident near Staging Yard		
Caliente-Indian Cove	3.0E-6	1.8E-9
Caliente-Upland	2.7E-3	1.6E-6
Eccles-North	3.4E-6	2.1E-9

K.2.7.1.2.2 Members of the Public. Members of the public near the Caliente-Indian Cove, Caliente-Upland, or Eccles-North Staging Yard could be potentially exposed to direct radiation from 9,495 shipping casks over 50 years of transporting spent nuclear fuel and high-level radioactive waste to the repository.

Table K-38 lists the collective radiation doses and impacts for these members of the public. The collective radiation dose for members of the public is estimated to range from 0.0039 to 0.026 person-rem. These radiation doses are based on the population in the year 2000 escalated to the year 2067. The highest radiation dose is for the Caliente-Indian Cove Staging Yard location, which also has the highest population. The lowest radiation dose is for the Eccles-North Staging Yard location, which has the lowest population. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would range from 2.4×10^{-6} to 1.6×10^{-5}, or about 1 chance in 400,000 to about 1 chance in 60,000.

Table K-39 lists the maximally exposed individual radiation doses and impacts for members of the public near the potential Staging Yard locations at Caliente-Indian Cove, Caliente-Upland, and Eccles-North. The maximally exposed individual at the Caliente-Indian Cove Staging Yard would be a resident who lives 1,600 meters (5,250 feet) from the Staging Yard. This individual would be exposed to each of the 9,495 shipping casks for a period of 2 hours per cask. The radiation dose for this individual is estimated to be 3.0×10^{-6} rem over the shipping campaign of 50 years. The probability of a latent cancer fatality for this individual is estimated to be 1.8×10^{-9}, or about 1 chance in 550,000,000.

The maximally exposed individual at the Caliente-Upland Staging Yard would be a resident who lives 400 meters (1,310 feet) from the Staging Yard. This individual would be exposed to each of the 9,495 shipping casks for a period of 2 hours per cask. The radiation dose for this individual is estimated to be

2.7×10^{-3} rem over the shipping campaign of 50 years. The probability of a latent cancer fatality for this individual is estimated to be 1.6×10^{-6}, or about 1 chance in 600,000.

The maximally exposed individual at the Eccles-North Staging Yard would be a resident who lives 1,500 meters (4,920 feet) from the Staging Yard. This individual would be exposed to each of the 9,495 shipping casks for a period of 2 hours per cask. The radiation dose for this individual is estimated to be 3.4×10^{-6} rem over the shipping campaign of 50 years. The probability of a latent cancer fatality for this individual is estimated to be 2.1×10^{-9}, or about 1 chance in 480,000,000.

K.2.7.1.3 Summary of Incident-Free Impacts

Table K-40 lists the incident-free collective radiation doses and impacts for workers en route to the repository, workers and members of the public located along the rail alignment route, involved and noninvolved workers at the Staging Yards, and members of the public near the Staging Yards for the Proposed Action and the Shared-Use Option.

The total collective radiation dose for en route workers and workers along the rail alignment route is estimated to range from 310 to 320 person-rem. For involved and noninvolved workers at the Staging Yards, the total collective radiation dose is estimated to be 250 person-rem. The total collective radiation dose for all workers (en route, along the rail alignment, and at the Staging Yards) is estimated to be 560 to 570 person-rem. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.34. The impacts for these workers would be the same for the Proposed Action and the Shared-Use Option.

The total collective radiation dose for members of the public along the Caliente rail alignment potentially exposed to radiation from cask trains en route to the repository was estimated to range from 0.087 to 0.21 person-rem. For members of the public near the Staging Yards, the total collective radiation dose is estimated to range from 0.0039 to 0.026 person-rem. The total collective radiation dose for all members of the public (along the rail alignment route and near the Staging Yards) is estimated to range from 0.091 to 0.24 person-rem. These radiation doses are based on the population in the year 2000 and escalated to the year 2067, and vary depending upon the location of the Staging Yard. The radiation doses are highest for those rail alignments and Staging Yard locations where the populations are the highest. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would range from 5.5×10^{-5} to 1.4×10^{-4}. The impacts for these members of the public would be the same for the Proposed Action and the Shared-Use Option.

The total collective radiation dose for all workers and members of the public is estimated to be 560 to 570 person-rem. More than 99 percent of the radiation dose is to workers; less than 1 percent of the radiation dose is to members of the public. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would be 0.34.

K.2.7.2 Transportation Accident Risks

This section presents the radiological transportation accident risks of shipping spent nuclear fuel and high-level radioactive waste from the Interchange Yard at Caliente or Eccles to the repository for the Proposed Action and the Shared-Use Option. Transportation risks were quantified in terms of dose risk, which is the sum of the products of the probabilities (dimensionless) and consequences (collective radiation doses in units of person-rem) of all potential transportation accidents. Transportation risks were also quantified in terms of latent cancer fatalities.

Table K-40. Summary of incident-free collective radiation doses and latent cancer fatalities for workers and members of the public for the Caliente rail alignment.

		Collective radiation dose (person-rem)						
Rail alignment	Staging Yard location	Total workers en route and along route	Total workers at Staging Yard	Total workers	Total public along route	Total public near Staging Yard	Total public	Total public and workers
Proposed Action and Shared-Use Option								
Highest population	Caliente-Indian Cove	3.2E+2	2.5E+2	5.7E+2	2.1E-1	2.6E-2	2.4E-1	5.7E+2
Highest population	Caliente-Upland	3.2E+2	2.5E+2	5.7E+2	2.1E-1	6.4E-3	2.2E-1	5.7E+2
Shortest distance	Caliente-Indian Cove	3.1E+2	2.5E+2	5.6E+2	1.8E-1	2.6E-2	2.1E-1	5.6E+2
Shortest distance	Caliente-Upland	3.1E+2	2.5E+2	5.6E+2	1.8E-1	6.4E-3	1.9E-1	5.6E+2
Longest distance	Eccles-North	3.2E+2	2.5E+2	5.7E+2	1.1E-1	3.9E-3	1.1E-1	5.7E+2
Lowest population	Eccles-North	3.1E+2	2.5E+2	5.6E+2	8.7E-2	3.9E-3	9.1E-2	5.6E+2
		Latent cancer fatalities						
Highest population	Caliente-Indian Cove	1.9E-1	1.5E-1	3.4E-1	1.3E-4	1.6E-5	1.4E-4	3.4E-1
Highest population	Caliente-Upland	1.9E-1	1.5E-1	3.4E-1	1.3E-4	3.9E-6	1.3E-4	3.4E-1
Shortest distance	Caliente-Indian Cove	1.9E-1	1.5E-1	3.4E-1	1.1E-4	1.6E-5	1.2E-4	3.4E-1
Shortest distance	Caliente-Upland	1.9E-1	1.5E-1	3.4E-1	1.1E-4	3.9E-6	1.1E-4	3.4E-1
Longest distance	Eccles-North	1.9E-1	1.5E-1	3.4E-1	6.4E-5	2.4E-6	6.6E-5	3.4E-1
Lowest population	Eccles-North	1.9E-1	1.5E-1	3.4E-1	5.2E-5	2.4E-6	5.5E-5	3.4E-1

Table K-41 lists the dose risks for the four rail alignments evaluated in the Rail Alignment EIS. The dose risks are estimated to range from 1.1×10^{-3} to 2.2×10^{-3} person-rem. The rail alignments that have the higher populations also have the higher dose risks. Also, because the number of shipping casks transported from Caliente or Eccles to the repository would be the same for the Proposed Action and for the Shared-Use Option, the dose risks are the same for the Proposed Action and Shared-Use Option. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose risk would range from 6.7×10^{-7} to 1.3×10^{-6}, or about 1 chance in 1,400,000 to about 1 chance in 700,000.

Table K-41. Radiological transportation accident risks for the Caliente rail alignment.

Rail alignment	Staging Yard location	Dose risk[a] (person-rem)	Latent cancer fatalities (LCFs)
Proposed Action and Shared-Use Option			
Highest population	Caliente	2.2E-3	1.3E-6
Shortest distance	Caliente	1.9E-3	1.1E-6
Longest distance	Eccles	1.3E-3	7.6E-7
Lowest population	Eccles	1.1E-3	6.7E-7

a. Dose risk is the sum of the products of the probabilities and consequences in person-rem of all potential transportation accidents.

K.2.7.3 Severe Transportation Accidents

This section presents the consequences of severe transportation accidents, known as maximum reasonably foreseeable transportation accidents, that could occur during the shipment of spent nuclear fuel and high-level radioactive waste to the repository from the Interchange Yard at Caliente or Eccles for the Proposed Action and the Shared-Use Option.

Because it is not possible to forecast the atmospheric conditions that might exist during a severe accident, consequences were determined using low wind speeds and stable atmospheric conditions (a wind speed of 0.89 meter per second [2.9 feet per second] and Class F stability). The severe accident scenario calculation methodology does not include a probabilistic component that includes the atmospheric stability, therefore stable conditions were assumed. The atmospheric concentrations estimated from these conditions would be exceeded only 5 percent of the time.

For the four rail alignments described in Table K-30, there were no urban areas as defined in U.S. Census Bureau population data. However, there were suburban areas and rural areas. Using alignment-specific 2000 census population data escalated to the year 2067, the average population density in suburban areas along the alignments ranged from 223 to 226 people per square kilometer (577 to 586 people per square mile), near Caliente and Goldfield. The average population density along rural areas, escalated to the year 2067, ranged from 0.346 to 0.585 people per square kilometer (0.896 to 1.51 people per square mile).

Table K-42 lists the impacts of the maximum reasonably foreseeable accident. This accident has a frequency of about 6×10^{-7} per year. If the maximum reasonably foreseeable accident were to occur in a suburban area, the population radiation dose would be 770 person-rem. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would be 0.46. If the maximum reasonably foreseeable accident were to occur in a rural area, the collective radiation dose would be 2 person-rem. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would be 1.2E-3.

Table K-42. Consequences of the maximum reasonably foreseeable accident in suburban and rural areas along the Caliente rail alignment.[a]

Proposed Action and Shared-Use Option	Suburban area[b]	Rural area[c]
Population radiation dose (person-rem)	770	2.0
Latent cancer fatalities	0.46	1.2E-3
Maximally exposed individual (rem)	34	34
Probability of latent cancer fatality	0.020	0.020
First responder radiation dose (rem)	0.14 – 2.0	0.14 – 2.0
Probability of latent cancer fatality	8.2×10^{-5} – 0.0012	8.2×10^{-5} – 0.0012

a. Consequences based on low wind speeds and stable atmospheric conditions.

b. Population density in the suburban area is 586 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

c. Population density in the rural area is 1.51 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

In either a suburban area or rural area, the radiation dose from the maximum reasonably foreseeable transportation accident for the maximally exposed individual located 330 meters (1,100 feet) from the accident would be 34 rem. The probability of an LCF for that individual is estimated to be 0.020.The radiation dose to a first responder would range from 0.14 to 2.0 rem. The probability of an LCF for this first responder is estimated to range from 8.2×10^{-5} to 0.0012.

Recovering 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 capability 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 been accomplished and DOE anticipates that if such a recovery was necessary, it would be accomplished using methods and equipment similar to those used in prior difficult recoveries.

K.2.7.4 Transportation Sabotage

This section presents the consequences of a sabotage event for shipments of spent nuclear fuel and high-level radioactive waste to the repository from the Interface with the Union Pacific Railroad Mainline on the Caliente alternative segment or the Eccles alternative segment.

For the four rail alignments described in Table K-30, there were no urban areas as defined in U.S. Census Bureau population data. However, there were suburban areas and rural areas. Using alignment-specific 2000 census population data escalated to the year 2067, the average population density in suburban areas along the alignments ranged from 223 to 226 people per square kilometer (577 to 586 people per square mile), near Caliente and Goldfield. The average population density along rural areas, escalated to the year 2067, ranged from 0.346 to 0.585 people per square kilometer (0.896 to 1.51 people per square mile).

Table K-43 lists the consequences of a potential sabotage event. The consequences would be the same for the Proposed Action and the Shared-Use Option. If the sabotage event occurred in a suburban area, the collective radiation dose is estimated to be 1,800 person-rem. Under the assumed conditions, the number of latent cancer fatalities based on the estimated dose would be 1.1.

Table K-43. Consequences of a sabotage event in suburban and rural areas along the Caliente rail alignment.[a]

Proposed Action and Shared-Use Option	Suburban area[b]	Rural area[c]
Population radiation dose (person-rem)	1,800	4.7
Latent cancer fatalities	1.1	0.0028
Maximally exposed individual (rem)	27	27
Probability of latent cancer fatality	0.016	0.016

a. Consequences based on moderate wind speeds and neutral atmospheric conditions.
b. Population density in the suburban area is 586 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.
c. Population density in the rural area is 1.51 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

If the sabotage event occurred in a rural area, the collective radiation dose is estimated to be 4.7 person-rem. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would be 0.0028.

If the sabotage event were to occur in either a suburban area or rural area, the maximally exposed individual would be located 100 meters (330 feet) from the sabotage event, at the location of maximum downwind air concentration. The radiation dose for the maximally exposed individual is estimated to be 27 rem. The probability of a latent cancer fatality for this individual is estimated to be 0.016.

K.2.8 RESULTS FOR THE MINA RAIL ALIGNMENT

K.2.8.1 Incident-Free Impacts

This section presents the radiological impacts of incident-free transportation for workers and members of the public. Impacts for the Proposed Action and the Shared-Use Option are presented for rail workers and escorts en route to the repository, for workers located at the Maintenance-of-Way Facility and at sidings, for workers at the Staging Yard at Hawthorne, and for members of the public along the rail alignment and near the Staging Yard at Hawthorne.

K.2.8.1.1 Workers and Members of the Public En Route to the Repository

K.2.8.1.1.1 Workers. During the shipment of spent nuclear fuel and high-level radioactive waste from Hazen, Nevada to the repository, workers would be potentially exposed to direct radiation from 9,495 shipping casks.

Table K-44 lists the collective radiation doses and impacts for these workers. Because dedicated trains would be used for transporting spent nuclear fuel and high-level radioactive waste from Hazen to the repository and under normal circumstances there would be no en route stops between Hazen and the repository, therefore there would be no radiation doses at stops for rail workers (engineers and conductors) or escorts. Because rail workers would be working in the cab of the locomotive and situated at a distance of at least 45.7 meters (150 feet) from the nearest cask, and would be shielded from radiation by the locomotive, there would be no radiation doses for these workers while en route to the repository.

The collective radiation dose for workers is estimated to be 310 to 340 person-rem, with longer alignments having higher estimated radiation doses. The radiation doses would be the same for the Proposed Action and the Shared-Use Option. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.18 to 0.20 or about 1 chance in 5. For perspective, in the United States the lifetime risk of dying from cancer is about 1 in 5.

Table K-44. Incident-free collective radiation doses and latent cancer fatalities for en route workers and members of the public for the Mina rail alignment (page 1 of 2).

		Collective radiation dose (person-rem)										
Rail alignment	Interchange location	En route rail workers[a]	En route rail workers at stops	En route escorts	En route escorts at stops	MOW[b] Facility workers	Workers located at sidings	Total en route workers	Off-link public along route	On-link public along route	Stops public along route	Total public along route
Proposed Action												
Highest population	Hazen	0.0E+0	0.0E+0	3.2E+2	0.0E+0	3.5E-2	0.0013	3.2E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Shortest distance	Hazen	0.0E+0	0.0E+0	3.1E+2	0.0E+0	3.5E-2	0.0013	3.1E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Longest distance	Hazen	0.0E+0	0.0E+0	3.4E+2	0.0E+0	3.5E-2	0.0013	3.4E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Lowest population	Hazen	0.0E+0	0.0E+0	3.3E+2	0.0E+0	3.5E-2	0.0013	3.3E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Shared-Use Option												
Highest population	Hazen	0.0E+0	0.0E+0	3.2E+2	0.0E+0	3.5E-2	0.0028	3.2E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Shortest distance	Hazen	0.0E+0	0.0E+0	3.1E+2	0.0E+0	3.5E-2	0.0028	3.1E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Longest distance	Hazen	0.0E+0	0.0E+0	3.4E+2	0.0E+0	3.5E-2	0.0028	3.4E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0
Lowest population	Hazen	0.0E+0	0.0E+0	3.3E+2	0.0E+0	3.5E-2	0.0028	3.3E+2	1.4E+0	0.0E+0	0.0E+0	1.4E+0

Table K-44. Incident-free collective radiation doses and latent cancer fatalities for en route workers and members of the public for the Mina rail alignment (page 2 of 2).

		Latent cancer fatalities										
Rail alignment	Interchange location	En route rail workers[a]	En route rail workers at stops	En route escorts	En route escorts at stops	MOW[b] Facility workers	Workers located at sidings	Total en route workers	Off-link public along route	On-link public along route	Stops public along route	Total public along route
Proposed Action												
Highest population	Hazen	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.1E-5	7.7E-7	1.9E-1	8.5E-4	0.0E+0	0.0E+0	8.5E-4
Shortest distance	Hazen	0.0E+0	0.0E+0	1.8E-1	0.0E+0	2.1E-5	7.7E-7	1.8E-1	8.2E-4	0.0E+0	0.0E+0	8.2E-4
Longest distance	Hazen	0.0E+0	0.0E+0	2.0E-1	0.0E+0	2.1E-5	7.7E-7	2.0E-1	8.3E-4	0.0E+0	0.0E+0	8.3E-4
Lowest population	Hazen	0.0E+0	0.0E+0	2.0E-1	0.0E+0	2.1E-5	7.7E-7	2.0E-1	8.1E-4	0.0E+0	0.0E+0	8.1E-4
Shared-Use Option												
Highest population	Hazen	0.0E+0	0.0E+0	1.9E-1	0.0E+0	2.1E-5	1.7E-6	1.9E-1	8.5E-4	0.0E+0	0.0E+0	8.5E-4
Shortest distance	Hazen	0.0E+0	0.0E+0	1.8E-1	0.0E+0	2.1E-5	1.7E-6	1.8E-1	8.2E-4	0.0E+0	0.0E+0	8.2E-4
Longest distance	Hazen	0.0E+0	0.0E+0	2.0E-1	0.0E+0	2.1E-5	1.7E-6	2.0E-1	8.3E-4	0.0E+0	0.0E+0	8.3E-4
Lowest population	Hazen	0.0E+0	0.0E+0	2.0E-1	0.0E+0	2.1E-5	1.7E-6	2.0E-1	8.1E-4	0.0E+0	0.0E+0	8.1E-4

a. Rail workers are engineers and conductors.
b. MOW = Maintenance-of-Way.

For workers who could potentially be exposed to radiation when cask trains pass by the Maintenance-of-Way Facility, the collective radiation dose is estimated to be 0.035 person-rem. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 2.1×10^{-5} or about 1 chance in 40,000. The impacts for these workers would be the same for the Proposed Action and the Shared-Use Option. In addition, the impacts for these workers would not depend on the length of the rail alignment.

For workers who could potentially be exposed when a train containing loaded casks passed a train containing empty casks or other materials at a siding, the collective radiation dose is estimated to be 0.0013 person-rem for the Proposed Action and 0.0028 person-rem for the Shared-Use Option. The radiation dose is higher for the Shared-Use Option because there would be increased rail traffic and therefore more opportunities for a train to be passed at a siding and workers exposed. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 7.7×10^{-7} for the Proposed Action and 1.7×10^{-6} for the Shared-Use Option, corresponding to about 1 chance in 1,200,000 and about 1 chance in 500,000.

The total collective radiation dose for all workers potentially exposed en route to the repository is estimated to range from 310 to 340 person-rem. The radiation dose for escorts accounts for more than 99 percent of the total radiation dose to workers. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to range from 0.18 to 0.20.

Table K-45 lists the maximally exposed individual radiation doses and impacts for all workers. The maximally exposed worker would be an escort. This worker is estimated to receive a radiation dose of 25 rem over the 50 years of operations, based on a 0.5 rem per year administrative dose limit for repository facilities (DIRS 174942-BSC 2005, Section 4.9.3.3) and a person working for up to 50 years escorting shipments. The probability of a latent cancer fatality for this worker is estimated to be 0.015 or about 1 chance in 60.

Table K-45. Incident-free maximally exposed individual radiation doses and latent cancer fatalities for en route workers and members of the public for the Mina rail alignment.

Severe accident case	Radiation dose (rem)	Latent cancer fatalities
Proposed Action		
Workers		
Escort (1 year of operations)	0.50	0.00030
Escort (50 years of operations)	25	0.015
Worker at Maintenance-of-Way Facility	8.8E-04	5.3E-07
Worker at siding	1.3E-4	7.7E-8
Members of the public		
Resident near rail line (18 meters [60 feet])	7.8E-3	4.7E-6
Shared-Use Option		
Workers		
Escort (1 year of operations)	0.50	0.00030
Escort (50 years of operations)	25	0.015
Worker at Maintenance-of-Way Facility	8.8E-04	5.3E-07
Worker at siding	2.8E-4	1.7E-7
Members of the public		
Resident near rail line (18 meters [60 feet])	7.8E-3	4.7E-6

An individual worker at the Maintenance-of-Way Facility was estimated to receive a radiation dose of 8.8 $\times 10^{-4}$ rem over 50 years of operations and assuming that the worker was exposed to all loaded casks that passed the facility. The probability of a latent cancer fatality for this worker is estimated to be 5.3×10^{-7}, or about 1 chance in 1,800,000.

An individual worker at a siding passed by loaded cask trains was estimated to receive a radiation dose of 1.3×10^{-4} rem for the Proposed Action and 2.8×10^{-4} rem for the Shared-Use Option over 50 years of operations and assuming that the worker was exposed to all loaded casks that passed a siding. The probability of a latent cancer fatality for this worker is estimated to be 7.7×10^{-8} (1 chance in 12,000,000) for the Proposed Action and 1.7×10^{-7} (1 chance in 5,800,000) for the Shared-Use Option.

K.2.8.1.1.2 Members of the Public. During the shipment of spent nuclear fuel and high-level radioactive waste from Hazen, Nevada, to the repository, members of the public along the rail alignment could be potentially exposed to direct radiation from 9,495 shipping casks.

Table K-44 lists the collective radiation doses and impacts for members of the public along the rail alignment. Because dedicated trains would be used for transporting spent nuclear fuel and high-level radioactive waste from Hazen to the repository and there would be no en route stops under normal circumstances, there would be no radiation doses at stops for members of the public. In addition, because two trains could not share the single railroad track simultaneously, there would be no on-link radiation doses for members of the public.

The collective radiation dose for members of the public potentially exposed along the rail alignment (off-link) is estimated to be 1.4 person-rem, for all rail alignments. These radiation doses are based on the population in the year 2000 escalated to the year 2067. The radiation doses for members of the public would be the same for the Proposed Action and the Shared-Use Option. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would range from 8.1×10^{-4} to 8.5×10^{-4}, or about 1 chance in 1,000. For perspective, in the United States the lifetime risk of dying from cancer is about 1 in 5.

Table K-45 lists the maximally exposed individual radiation doses and impacts for members of the public. The maximally exposed individual would be a resident who lives 18 meters (60 feet) from the rail line. This individual would be exposed to each of 9,495 shipping casks as they passed by en route to the repository. The radiation dose for this individual is estimated to be 0.0078 rem over the course of a shipping campaign of 50 years. The probability of a latent cancer fatality for this individual is estimated to be 4.7×10^{-6} or 1 chance in 200,000.

K.2.8.1.2 Workers and Members of the Public at the Staging Yard

K.2.8.1.2.1 Workers. When shipping casks arrive at the Staging Yard at Hawthorne, the railcars containing the shipping cask would be removed from the train, an inspection conducted, and the railcar transferred to the train to be transported to the repository. The escorts that had accompanied the shipping cask from its point of origin would also be present during this inspection. These railcar-handling, escort, and inspection workers would be potentially exposed to direct radiation from 9,495 shipping casks over 50 years of transporting spent nuclear fuel and high-level radioactive waste to the repository. Noninvolved workers at the Staging Yard would also be potentially exposed to direct radiation from the casks.

Table K-46 lists the collective radiation doses and impacts for these workers. The radiation dose to workers at the Staging Yard would be the same for the Proposed Action and the Shared-Use Option because the number of shipping casks handled at the Staging Yard would be the same for the Proposed Action and Shared-Use Option.

Table K-46. Incident-free collective radiation doses and latent cancer fatalities at the Staging Yard at Hawthorne for workers and members of the public.

	Collective radiation dose (person-rem)			
Staging Yard location	Involved workers at Staging Yard	Noninvolved workers at Staging Yard	Total workers at Staging Yard	Public near Staging Yard
Proposed Action and Shared-Use Option				
Hawthorne	2.4E+2	1.0E+1	2.5E+2	0.0E+0
	Latent cancer fatalities			
Staging Yard location	Involved workers at Staging Yard	Noninvolved workers at Staging Yard	Total workers at Staging Yard	Public near Staging Yard
Proposed Action and Shared-Use Option				
Hawthorne	1.4E-1	6.3E-3	1.5E-1	0.0E+0

The collective radiation dose for involved workers at the Staging Yard is estimated to be 240 person-rem. These radiation doses are in large part dependent on the time that a cask spent in the Staging Yard, which is estimated to be 2 hours, and on the close proximity of the inspector to the cask, which is estimated to be 1 meter (3.3 feet). In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.14.

The collective radiation dose for noninvolved workers at the Staging Yard is estimated to be 10 person-rem. These radiation doses are in large part dependent on the time that a noninvolved worker is assumed to spend in the Staging Yard, which is estimated to be 2 hours, at an estimated distance of 100 meters (330 feet) from the casks. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.0063.

The total collective radiation dose for involved and noninvolved workers at the Staging Yard is estimated to be 250 person-rem. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.15.

Table K-47 lists the maximally exposed individual radiation doses and impacts for workers at the Staging Yard. The maximally exposed worker would be an inspector, rail worker, or escort. This individual is estimated to receive a radiation dose of 25 rem over the 50 years of operations, based on a 0.5 rem per year administrative dose limit at repository facilities (DIRS 174942-BSC 2005, Section 4.9.3.3) for a person working for up to 50 years at the Staging Yard. The probability of a latent cancer fatality for this worker is estimated to be 0.015 or about 1 chance in 60.

Table K-47. Incident-free maximally exposed individual radiation doses and latent cancer fatalities at the Staging Yard at Hawthorne for workers and members of the public.

Proposed Action and Shared-Use Option	Radiation dose (rem)	Latent cancer fatalities
Workers		
Escort, rail worker, or inspector (1 year of operations)	0.50	0.00030
Escort, rail worker, or inspector (50 years of operations)	25	0.015
Members of the public		
Business near Staging Yard	1.8E-4	1.1E-7

K.2.8.1.2.2 Members of the Public. Members of the public near the Staging Yard at Hawthorne could be potentially exposed to direct radiation from 9,495 shipping casks over 50 years of transporting spent nuclear fuel and high-level radioactive waste to the repository.

Tables K-46 and K-47 list the radiation doses and impacts for these members of the public. Based on 2000 census data, there is no resident population within 800 meters (0.5 mile) of the Staging Yard. Therefore, the collective radiation dose for members of the public is estimated to zero. There is, however, a business located 660 meters (2,170 feet) from the Staging Yard. The radiation dose for a person at this business is estimated to be 0.00018 rem, assuming that an individual was exposed to each of the 9,495 shipping casks for a period of 2 hours per cask. The probability of a latent cancer fatality for this individual is estimated to be 1.1×10^{-7}, or about 1 chance in 9,000,000.

K.2.8.1.3 Summary of Incident-Free-Impacts

Table K-48 lists the incident-free collective radiation doses and impacts for workers en route to the repository, workers and members of the public located along the rail alignment route, involved and noninvolved workers at the Staging Yard at Hawthorne, and members of the public near the Staging Yard at Hawthorne for the Proposed Action and the Shared-Use Option.

The total collective radiation dose for en route workers and workers along the rail alignment route is estimated to range from 310 to 340 person-rem. For involved and noninvolved workers at the Staging Yard at Hawthorne, the total collective radiation dose is estimated to be 250 person-rem. The total collective radiation dose for all workers (en route, along the rail alignment, and at the Staging Yard) is estimated to be 550 to 580 person-rem. In the potentially exposed population of workers, the probability of a latent cancer fatality is estimated to be 0.33 to 0.35. The impacts for these workers would be the same for the Proposed Action and the Shared-Use Option.

The total collective radiation dose for members of the public along the Mina rail alignment potentially exposed to radiation from cask trains en route to the repository was estimated to be 1.4 person-rem. Since there are no members of the public near the Staging Yard at Hawthorne, the total collective radiation dose for members of the public near the Staging Yards is zero. The total collective radiation dose for all members of the public (along the rail alignment route and near the Staging Yard) is estimated be 1.4 person-rem.

These radiation doses are based on the population in the year 2000 and escalated to the year 2067. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would range from 8.1×10^{-4} to 8.5×10^{-4}. The impacts for these members of the public would be the same for the Proposed Action and the Shared-Use Option.

The total collective radiation dose for all workers and members of the public is estimated to range from 550 to 580 person-rem. More than 99 percent of the radiation dose is to workers; less than 1 percent of the radiation dose is to members of the public. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would range from 0.33 to 0.35.

K.2.8.2 Transportation Accident Risks

This section presents the radiological transportation accident risks of shipping spent nuclear fuel and high-level radioactive waste from Hazen, Nevada, to the repository for the Proposed Action and the Shared-Use Option. Transportation risks were quantified in terms of dose risk, which is the sum of the products of the probabilities (dimensionless) and consequences (collective radiation doses in units of person-rem) of all potential transportation accidents. Transportation risks were also quantified in terms of latent cancer fatalities.

Table K-48. Summary of incident-free collective radiation doses and latent cancer fatalities for workers and members of the public for the Mina rail alignment.

Rail alignment	Staging Yard location	Total workers en route and along route	Total workers at Staging Yard	Total workers	Total public along route	Total public near Staging Yard	Total public	Total public and worker
		Collective radiation dose (person-rem)						
Proposed Action and Shared-Use Option								
Highest population	Hawthorne	3.2E+2	2.5E+2	5.7E+2	1.4E+0	0.0E+0	1.4E+0	5.7E+2
Shortest distance	Hawthorne	3.1E+2	2.5E+2	5.5E+2	1.4E+0	0.0E+0	1.4E+0	5.5E+2
Longest distance	Hawthorne	3.4E+2	2.5E+2	5.8E+2	1.4E+0	0.0E+0	1.4E+0	5.8E+2
Lowest population	Hawthorne	3.3E+2	2.5E+2	5.8E+2	1.4E+0	0.0E+0	1.4E+0	5.8E+2
		Latent cancer fatalities						
Highest population	Hawthorne	1.9E-1	1.5E-1	3.4E-1	8.5E-4	0.0E+0	8.5E-4	3.4E-1
Shortest distance	Hawthorne	1.8E-1	1.5E-1	3.3E-1	8.2E-4	0.0E+0	8.2E-4	3.3E-1
Longest distance	Hawthorne	2.0E-1	1.5E-1	3.5E-1	8.3E-4	0.0E+0	8.3E-4	3.5E-1
Lowest population	Hawthorne	2.0E-1	1.5E-1	3.5E-1	8.1E-4	0.0E+0	8.1E-4	3.5E-1

Table K-49 lists the dose risks for the four rail alignments evaluated in the Rail Alignment EIS. The dose risks are estimated to range from 1.2×10^{-2} to 1.3×10^{-2} person-rem. The rail alignments that have the higher populations also have the higher dose risks. Also, because the number of shipping casks transported from Hazen to the repository would be the same for the Proposed Action and for the Shared-Use Option, the dose risks are the same for the Proposed Action and Shared-Use Option. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose risk would range from 7.4×10^{-6} to 7.7×10^{-6}, or about 1 chance in 100,000.

Table K-49. Radiological transportation accident risks for the Mina rail alignment.

Rail alignment	Staging Yard location	Dose risk[a] (person-rem)	Latent cancer fatalities (LCFs)
Proposed Action and Shared-Use Option			
Highest population	Hawthorne	1.3E-2	7.7E-6
Shortest distance	Hawthorne	1.2E-2	7.4E-6
Longest distance	Hawthorne	1.3E-2	7.6E-6
Lowest population	Hawthorne	1.2E-2	7.4E-6

a. Dose risk is the sum of the products of the probabilities and consequences in person-rem of all potential transportation accidents.

K.2.8.3 Severe Transportation Accidents

This section presents the consequences of severe transportation accidents, known as maximum reasonably foreseeable transportation accidents, that could occur during the shipment of spent nuclear fuel and high-level radioactive waste to the repository from Hazen, Nevada, for the Proposed Action and the Shared-Use Option.

Because it is not possible to forecast the atmospheric conditions that might exist during a severe accident, consequences were determined using low wind speeds and stable atmospheric conditions (a wind speed of 0.89 meter per second [2.9 feet per second] and Class F stability). The severe accident scenario calculation methodology does not include a probabilistic component that includes the atmospheric stability, therefore stable conditions were assumed. The atmospheric concentrations estimated from these conditions would be exceeded only 5 percent of the time.

For the four rail alignments described in Table K-31, there were no urban areas as defined in U.S. Census Bureau population data. However, there were suburban areas and rural areas. Using alignment-specific 2000 census population data escalated to the year 2067, the average population density in suburban areas along the alignments ranged from 542 to 589 people per square kilometer (1,400 to 1,530 people per square mile), near Silver Springs, Nevada. The average population density along rural areas, escalated to the year 2067, ranged from 3.94 to 4.33 people per square kilometer (10.2 to 11.2 people per square mile).

Table K-50 lists the impacts of the maximum reasonably foreseeable accident. This accident has a frequency of about 7×10^{-7} per year. If the maximum reasonably foreseeable accident were to occur in a suburban area, the population radiation dose would be 2,000 person-rem. Under the assumed conditions, the number of latent cancer fatalities based on the estimated dose would be 1.2. If the maximum reasonably foreseeable accident were to occur in a rural area, the collective radiation dose would be 15 person-rem. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would be 8.9E-3.

Table K-50. Consequences of the maximum reasonably foreseeable accident in suburban and rural areas along the Mina rail alignment.[a]

Proposed Action and Shared-Use Option	Suburban area[b]	Rural area[c]
Population radiation dose (person-rem)	2,000	15
Latent cancer fatalities	1.2	8.9×10^{-3}
Maximally exposed individual (rem)	34	34
Probability of latent cancer fatality	0.020	0.020
First responder radiation dose (rem)	0.14 – 2.0	0.14 – 2.0
Probability of latent cancer fatality	8.2×10^{-5} – 0.0012	8.2×10^{-5} – 0.0012

a. Consequences based on low wind speeds and stable atmospheric conditions.

b. Population density in the suburban area is 1,530 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

c. Population density in the rural area is 11.2 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

In either a suburban area or rural area, the radiation dose from the maximum reasonably foreseeable transportation accident for the maximally exposed individual located 330 meters (1,100 feet) from the accident would be 34 rem. The probability of an LCF for that individual is estimated to be 0.020.

The radiation dose to a first responder would range from 0.14 to 2.0 rem. The probability of an LCF for this first responder is estimated to range from 8.2×10^{-5} to 0.0012.

Recovering 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 capability 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 been accomplished and DOE anticipates that if such a recovery was necessary, it would be accomplished using methods and equipment similar to those used in prior difficult recoveries.

K.2.8.4 Transportation Sabotage

This section presents the consequences of a potential sabotage event for shipments of spent nuclear fuel and high-level radioactive waste to the repository from Hazen, Nevada, for the Proposed Action and the Shared-Use Option.

For the four rail alignments described in Table K-31, there were no urban areas as defined in U.S. Census Bureau population data. However, there were suburban areas and rural areas. Using alignment-specific 2000 census population data escalated to the year 2067, the average population density in suburban areas along the alignments ranged from 542 to 589 people per square kilometer (1,400 to 1,530 people per square mile), near Silver Springs, Nevada. The average population density along rural areas, escalated to the year 2067, ranged from 3.94 to 4.33 people per square kilometer (10.2 to 11.2 people per square mile).

Table K-51 lists the consequences of a potential sabotage event. The consequences would be the same for the Proposed Action and the Shared-Use Option. If the sabotage event occurred in a suburban area, the collective radiation dose is estimated to be 4,700 person-rem. Under the assumed conditions, the number of latent cancer fatalities based on the estimated dose would be 2.8.

If the sabotage occurred in a rural area, the collective radiation dose is estimated to be 35 person-rem. Under the assumed conditions, the probability of a latent cancer fatality based on the estimated dose would be 0.021.

Table K-51. Consequences of a sabotage event in suburban and rural areas along the Mina rail alignment.[a]

Proposed Action and Shared-Use Option	Suburban area[b]	Rural area[c]
Population radiation dose (person-rem)	4,700	35
Latent cancer fatalities	2.8	0.021
Maximally exposed individual (rem)	27	27
Probability of latent cancer fatality	0.016	0.016

a. Consequences based on moderate wind speeds and neutral atmospheric conditions.
b. Population density in the suburban area is 1,530 people per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.
c. Population density in the rural area is 11.2 per square mile; to convert people per square mile to people per square kilometer, multiply by 0.3861.

If the sabotage event were to occur in either a suburban area or rural area, the maximally exposed individual would be located 100 meters (330 feet) from the sabotage event, at the location of maximum downwind air concentration. The radiation dose for the maximally exposed individual is estimated to be 27 rem. The probability of a latent cancer fatality for this individual is estimated to be 0.016.

K.3 Transportation Topical Areas

This section discusses additional topics identified during the scoping process for the Nevada Rail Corridor SEIS, the Rail Alignment EIS, and the Repository SEIS.

K.3.1 COST OF CLEANUP

According to the Nuclear Regulatory Commission 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 resulting radioactive contamination after the accident. Factors included are 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 how the land is used; the standard established for the allowable level of residual contamination following cleanup and the decontamination method used; and the technical requirements for and location for disposal of contaminated materials.

Because it would be necessary to specify each of the factors to estimate clean up costs, any estimate for a single accident would be highly uncertain and speculative. Nonetheless, to provide a gauge of the costs that could be incurred, DOE examined past studies of costs of cleanup following hypothetical accidents that would involve uncontrolled releases of radioactive materials.

A study of the impacts of transporting radioactive materials conducted by the Nuclear Regulatory Commission 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. estimated that costs could range from about $90 million to $2 billion for a severe spent nuclear fuel transportation accident in an urban area (DIRS 155054-Finley et al 1980, Table 6-9). 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 estimated that contamination would affect between 0.063 to 4.3 square kilometers (0.024 to 1.7 square miles). 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 would be 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 ($98 million to $1 billion per square mile) that would need to be cleaned up. The study also 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 ($230 million to $1 billion per square mile).

The National Aeronautics and Space Administration studied potential accidents for the Cassini mission, which used a plutonium powered electricity generator. The Agency 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 Agency assumed cleanup costs would be $5 million per square kilometer ($13 million per square mile) if removal and disposal of contaminated soil were not required and $50 million per square kilometer ($130 million per square mile) if those activities were required. For a reentry accident that would occur over land, the study estimated that the contaminated land area would range from about 1,500 to 5,700 square kilometers (580 to 2,200 square miles) (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, NASA estimated that costs would 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 (0.58 to 7.7 square miles). As in the 1995 study, these estimates were based on cleanup costs in the range of $5 million to $50 million per square kilometer ($13 million to $130 million per square mile).

Using only the estimates provided by these studies, the costs of cleanup following a severe transportation accident in which radioactive material was released would 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 made regarding 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 may also 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 in transporting 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 by the various studies discussed above. During the maximum reasonably foreseeable accident, about 30 curies (mostly cesium) would be released. This is about 50 times less than used by Sandquist in his study (1,630 curies) and 20 times less than the release used in the estimates provided by the Nuclear Regulatory Commission 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 (where 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, the Department believes that the cost of cleaning up following such an accident would 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 involving releases of radioactive materials to the environment is $10.26 billion (see Appendix L).

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 the Rail Alignment EIS, up to $189.7 billion for accidents involving rail casks (DIRS 181756-Lamb, Resnikoff and Moore 2001, p. 48) and up to $299.4 billion for sabotage involving a rail cask (DIRS 181892-Lamb, Hintermann and Resnikoff 2002, p. 15). The state estimated these costs based on contamination levels that were estimated 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. Therefore, DOE believes that the State of Nevada estimates are unrealistic and that they do not represent the reasonably foreseeable cleanup costs of severe transportation accidents.

K.3.2 UNIQUE LOCAL CONDITIONS

Scoping comments on the Rail Alignment EIS stated that the unique local conditions in Nevada require special consideration in the transportation accident analysis. In the Rail Alignment EIS, DOE analyzed a range of severe accidents and their frequencies of occurrence (see Table K-33). The annual probabilities (frequencies of occurrence) provided in Table K-33 reflect the probability that the severe transportation accidents in Cases 1 through 20 (DIRS 152476-Sprung et al. 2000, all) could occur anywhere along the rail alignments. If analyses were prepared for specific locations, the annual probability of these severe accident cases would change because the probability of an accident at a specific location along the rail alignment would be much less than the probability of an accident at any location along the rail alignment. For instance, the annual probability of a Case 20 severe accident (the maximum reasonably foreseeable accident) occurring on the Caliente or Mina rail alignment ranges from 6×10^{-7} to 7×10^{-7}. At any 1-kilometer (0.62-mile)-long location along the rail alignments, the annual probability of this accident would be about 1.2×10^{-9}, which is nearly 2 orders of magnitude below that which is reasonably foreseeable. For these specific locations, the most severe accident that would be reasonably foreseeable (with an annual probability greater than 1×10^{-7}) would be an accident similar to Case 21 from *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, pp. 7-73 and 7-76). This particular accident would not result in any release of radioactive material from the cask, and thus would result in smaller consequences than the maximum reasonably foreseeable accident that DOE evaluated, less than 2×10^{-5} latent cancer fatality, as compared with 0.0012 to 0.46 latent cancer fatality reported in Table K-42, or 0.0089 to 1.2 latent cancer fatalities reported in Table K-50 for the maximum reasonably foreseeable transportation accident in a rural or suburban area.

K.3.3 COMPREHENSIVE RISK ASSESSMENT

The State of Nevada recommended that comprehensive risk assessment should be used as a substitute for probabilistic risk assessment in the transportation analysis.

The methods used to calculate transportation impacts are state-of-the-art. As a consequence, DOE believes that the Rail Alignment EIS adequately analyzes the environmental impacts that could result from shipping spent nuclear fuel and high-level waste and a “comprehensive risk assessment” is neither required nor necessary.

K.3.4 USE OF NUREG/CR-6672 TO ESTIMATE ACCIDENT RELEASES

The evaluations of the radiological impacts of transportation accidents presented in the Yucca Mountain FEIS (DIRS 155970-DOE 2002, Chapter 6) are based on data presented in NUREG/CR-6672 *Reexamination of Spent Nuclear Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000) 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 of 1977, the Nuclear Regulatory Commission (NRC or the Commission) issued a generic EIS (*Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes*, NUREG-0170 [DIRS 101892-NRC 1977]). That EIS addressed environmental impacts associated with the transport of all types of radioactive material by all transport modes (road, rail, air, and water), and provided the basis under the National Environmental Policy Act (NEPA) for the NRC to issue general licenses for transportation of radioactive material under 10 CFR 71. Based in part on the findings of NUREG-0170, the Commission concluded that “present regulations are adequate to protect the public against unreasonable risk from the transport of radioactive materials” (46 *Federal Register* 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 whether the estimates of environmental impacts in NUREG-0170 remained valid. According to the Commission, the reexamination was initiated (1) because many spent fuel shipments are expected to be made during the next few decades, (2) because these shipments will be made to facilities along routes and in casks not specifically examined by NUREG-0170, and (3) because the risks associated with these shipments can be estimated using new data and improved methods of analysis. In 2000, the Commission 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).

Some have been critical of NUREG/CR-6672; for example, see *Review of NUREG/CR-6672, Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 181884-Lamb and Resnikoff 2000, all) and *Worst Case Credible Nuclear Transportation Accidents: Analysis for Urban and Rural Nevada* (DIRS 181756-Lamb, Resnikoff, and Moore 2001, Appendix A). However, the Commission has stated that many of the purported methodological flaws appear to be related to differing views regarding assumptions and that critical comments do not appear to recognize that many of the assumptions used overstated risks (DIRS 181603-Shankman 2001).

Supporting the NRC’s assessment, in its review of NUREG/CR-6672 (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]), the National Academy of Sciences Committee on Transportation of Radioactive Waste noted that the conservative assumptions used were reasonable for producing bounding estimates of accident consequences.

Conversely, the Committee indicated less confidence regarding the analysis of overall transport risks presented in the report. Here 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 NRC comments, DOE has concluded that NUREG/CR-6672 represents the best available information for use in estimating the consequences of transportation accidents involving spent nuclear fuel and high-level waste and has used NUREG/CR-6672 in the Rail Alignment EIS.

K.4 Glossary

absorbed dose	A measure of the energy deposited in a medium by ***ionizing radiation***. It is equal to the energy deposited per unit mass of medium.
accident	An unplanned sequence of events that results in undesirable consequences. Examples in the Rail Alignment EIS include an inadvertent release of ***radiation*** from the ***casks*** or hazardous materials from their containers, train derailments, vehicular accidents, and construction-related accidents that could affect workers.
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.***
atomic number	The number of ***protons*** in an atom's ***nucleus***.
atomic weight	The relative mass of an atom based on a scale in which a specific carbon atom (carbon-12) is assigned a mass value of 12. Also known as relative ***atomic mass***.
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.***
boiling-water reactor (BWR)	A ***nuclear reactor*** that uses boiling water to produce steam to drive a turbine.
burnup	The total energy released per initial unit mass of nuclear fuel as a result of ***irradiation***. The commonly used units of burnup are megawatt-days per metric ton of heavy metal (MWd/MTHM).
cancer	A malignant tumor of potentially unlimited growth, capable of invading surrounding tissue or spreading to other parts of the body.

canister	An unshielded metal container used as: (1) a pour mold in which molten vitrified ***high-level radioactive waste*** can solidify and cool; (2) the container in which DOE and electric utilities place intact ***spent nuclear fuel***, loose rods, or nonfuel components for shipping or storage; or (3) in general, a container used to provide ***radionuclide*** confinement. Canisters are used in combination with specialized overpacks that provide structural support, ***shielding*** or confinement for storage, transportation, and emplacement. Overpacks used for transportation are usually referred to as transportation ***casks***; those used for emplacement in a ***repository*** are referred to as waste packages.
cask	A heavily shielded container that meets applicable regulatory requirements used to ship ***spent nuclear fuel*** or ***high-level radioactive waste***.
cloudshine	***Irradiation*** of the human body by ***neutrons*** and ***gamma rays*** emitted by the passing plume of ***radioactive*** material.
collective dose	See ***population dose***.
committed effective dose equivalent	Dose delivered to specified organs or tissues over a specified period of time following an acute intake of a ***radionuclide*** by ingestion, inhalation, or dermal absorption. Time period over which committed doses are calculated normally is 50 years for intakes by adult or from age at intake to age 70 for intakes by other age groups.
conditional probability	The probability of an ***accident*** of a given severity category, given that an accident occurs.
cosmic radiation	A variety of high-energy particles including ***protons*** that bombard the Earth from outer space. They are more intense at higher altitudes than at sea level, where the Earth's atmosphere is most dense and provides the greatest protection.
decay (radioactive)	The process in which one ***radionuclide*** spontaneously transforms into one or more different radionuclides called ***decay products***.
decay product	A ***nuclide*** resulting from the ***radioactive decay*** of a parent isotope or precursor nuclide.
decay time	The time since the spent nuclear fuel has been discharged from the reactor.
dose (radioactive)	The amount of ***radioactive*** energy taken into (absorbed by) living tissues. See ***effective dose equivalent***.

dose equivalent	(1) The number (corrected for background) zero and above that is recorded as representing an individual's ***dose*** from external ***radiation*** sources or internally deposited ***radioactive*** materials; (2) the product of the absorbed dose in ***rads*** and a quality factor; (3) the product of the absorbed dose, the quality factor, and any other modifying factor. The dose equivalent quantity is used for comparing the biological effectiveness of different kinds of radiation (based on the quality of radiation and its spatial distribution in the body) on a common scale; it is expressed in ***rem***.
dose rate	The ***dose*** per unit time.
effective dose equivalent	Often 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.
electron	A stable elementary particle that is the negatively charged constituent of ordinary matter.
enrichment	The fraction of atoms of a specified isotope in a mixture of isotopes of the same element when this fraction exceeds that in the naturally occurring mixture. By convention, uranium enrichment is given on a weight basis.
exposure (to radiation)	The condition of being subject to the effects of or potentially acquiring a ***dose*** of ***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.
fission	The splitting of a ***nucleus*** into at least two other nuclei, resulting in the release of two or three ***neutrons*** and a relatively large amount of energy.
fission products	***Radioactive*** or nonradioactive atoms produced by the ***fission*** of heavy atoms, such as uranium.
fuel assembly	A number of fuel elements held together by structural materials, used in a ***nuclear reactor***; sometimes called a fuel bundle.
gamma ray	The most penetrating type of radiant nuclear energy. It does not contain particles and can be stopped by dense materials such as concrete or lead. See ***ionizing radiation.***
geologic repository	A system for the disposal of ***radioactive*** waste in excavated geologic media, including surface and subsurface areas of operation, and the adjacent part of the geologic setting that provides isolation of the radioactive waste in a controlled area.
groundshine	The ***radiation dose*** received from an area on the ground where ***radioactivity*** has been deposited by a ***radioactive*** plume or cloud.

half-life	The time in which half the atoms of a ***radioactive*** substance ***decay*** to another nuclear form. Half-lives range from millionths of a second to billions of years depending on the stability of the nuclei.
high-level radioactive waste	The highly ***radioactive*** material that resulted from the reprocessing of ***spent nuclear fuel***, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains ***fission products*** in sufficient concentrations.
hormesis	A dose response phenomenon characterized by a low dose stimulation, high dose inhibition, resulting in either a J-shaped or an inverted U-shaped dose response.
ion	An atom or group of atoms that carries a positive or negative charge as a result of having lost or gained one or more ***electrons***.
ionizing radiation	(1) ***Alpha particles***, ***beta particles***, ***gamma rays***, ***X-rays***, ***neutrons***, high-speed ***electrons***, high-speed ***protons***, and other particles capable of producing ions. (2) Any ***radiation*** capable of displacing electrons from an atom or molecule, thereby producing ions.
irradiation	***Exposure*** to ***radiation***.
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.
millirem	A unit of ***radiation dose*** that is equivalent to one one-thousandth of a ***rem***.
neutron	An atomic particle with no charge and an atomic mass of 1; a component of all atoms except hydrogen; frequently released as ***radiation***.
neutron radiation	See ***ionizing radiation***.
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***.
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.
person-rem	A unit used to measure the ***radiation exposure*** to an entire group and to compare the effects of different amounts of radiation on groups of people; it is the product of the average ***dose equivalent*** (in ***rem***) to a given organ or tissue multiplied by the number of persons in the population of interest.
photon	Quantum of electromagnetic radiation, having no charge or mass, that exhibits both particle and wave behavior, such as a ***gamma*** or ***x-ray***.

pressurized-water reactor (PWR)	A ***nuclear*** power ***reactor*** that uses water under pressure as a coolant. The water boiled to generate steam is in a separate system.
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.
population dose	A summation of the ***radiation doses*** received by individuals in an ***exposed*** population; equivalent to ***collective dose***; expressed in ***person-rem***.
rad	A unit of absorbed ***radiation*** dose in terms of energy. One rad equals 100 ergs of energy absorbed per gram of tissue.
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***.
release fraction	The fraction of material released during an accident.
rem	A unit of ***dose equivalent***. The dose equivalent in rems equals the absorbed dose in ***rads*** in tissue multiplied by the appropriate quality factor and possibly other modifying factors. Derived from roentgen equivalent man, referring to the dosage of ***ionizing radiation*** that will cause the same biological effect as one roentgen of ***X-ray*** or ***gamma ray*** exposure. One rem equals 0.01 sievert.
repository	See ***geologic repository***.
shielding	Any material that provides ***radiation*** protection.
source term	Types and amounts of ***radionuclides*** that are the source of a potential release of ***radioactivity***.

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 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 g. Nonfuel assembly hardware and structural parts of assemblies resulting from consolidation in canisters
subatomic particles	Any particle smaller than an atom.
total dose	The ***radiation dose*** to an individual or a group of people.
X-rays	Penetrating electromagnetic ***radiation*** having a wavelength much shorter than that of visible light. X-rays are identical to ***gamma rays*** but originate outside the ***nucleus***, either when the inner orbital ***electrons*** of an excited atom return to their normal state or when a metal target is bombarded with high-speed electrons.

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APPENDIX L

SUPPLEMENTAL TRANSPORTATION INFORMATION

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SUPPLEMENTAL TRANSPORTATION INFORMATION

L.1 Introduction

The U.S. Department of Energy (DOE or the Department) developed this appendix to provide general background information on transportation-related topics and to help readers understand how the transportation system would operate within the regulatory framework for the transportation of spent nuclear fuel and high-level radioactive waste. Section L.2 discusses transportation regulations, Section L.3 describes the components of a transportation system, and Section L.4 discusses operational practices. Section L.5 describes cask safety and testing. Section L.6 discusses emergency response, and Section L.7 describes available assistance for state, local, and American Indian tribal governments for emergency response planning. Section L.8 discusses DOE plans for transportation security, and Section L.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.*]). Section L.10 presents the National Academy of Sciences findings and recommendations.

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 (CFR).

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.

L.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 regulations. 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 United States Code [U.S.C.] 1801 *et seq.*), directs the U.S. Department of Transportation to develop transportation safety standards for hazardous materials in commerce, 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 (NWPA) (42 U.S.C. 10101 *et seq.*), requires that all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain be in NRC-certified casks and abide by NRC regulations related to advance notification of state and local governments. This section discusses the key regulations that govern the transportation of spent nuclear fuel and high-level radioactive waste.

L.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. Pursuant to Section 180(a) of the NWPA, all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be in packages certified for such purposes by the NRC. 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 L.4.10 discusses off-normal 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.

L.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 L-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 L-1also 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.

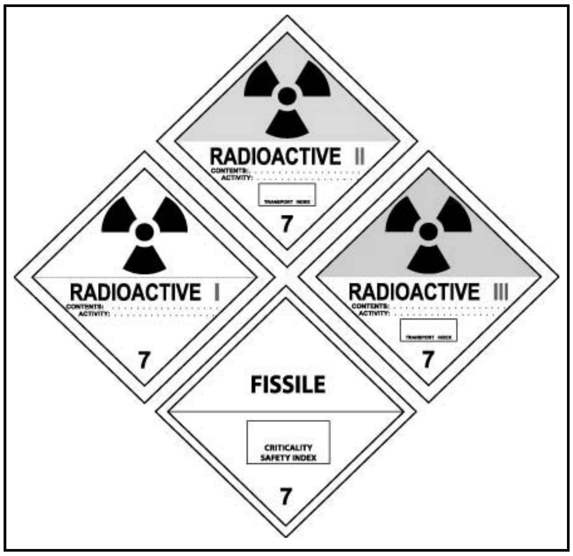

Figure L-1. Radioactive material shipment labels.

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 L-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 L-2. Radioactive hazard communication placard.

L.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.

L.2.4 ROUTING

In accordance with U.S. Department of Transportation regulations, shipments of Highway Route-Controlled Quantities of Radioactive Materials, such as spent nuclear fuel and high-level radioactive waste, would be shipped using preferred routes that reduce time in transit [49 CFR 397.101(b)]. A preferred route is an Interstate system highway, including beltways and bypasses or an alternative route selected by a state or tribal routing agency in accordance with 49 CFR 397.103 using *Guidelines for Selecting Preferred Highway Routes for Highway Route-Controlled Quantity Shipments of Radioactive Materials* or an equivalent routing analysis that adequately considers overall risk to the public. Factors for analysis by the state or tribal routing agency can include accident rates, traffic counts, distance, vehicle speeds, population density, land use, timeliness, and availability of emergency response capabilities. Substantive consultation with affected jurisdictions is required prior to designating an alternative route to ensure consideration of all impacts and continuity of designated route. 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 (49 CFR 397.203).

Railroads are privately owned and operated, and shippers and rail carriers determine routes based on a variety of factors. Route selection for shipments to Yucca Mountain would involve discussions between DOE and the chosen rail carriers, with consideration of input from other stakeholders. Federal rules do not prescribe specific routes for spent nuclear fuel and high-level radioactive waste shipments by rail, although certain factors, as described below, must be considered in route selection.

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration, in coordination with the Federal Railroad Administration and the Transportation Security Administration, has issued an Interim Final Rule revising requirements in the Hazardous Materials Regulations applicable to the safe and secure transportation of certain hazardous materials transported in commerce by rail (71 FR 20752, April 16, 2008). The rule encompasses, among other materials, Highway Route-Controlled Quantities of Class 7 (Radioactive) Material, as defined by 49 CFR 173.403, that are transported by rail. The Interim Final Rule requires rail carriers to compile annual data on these shipments, use the data to analyze safety and security risks along rail routes where those materials are transported, assess alternative routing options, and make routing decisions based on those assessments to select the safest and most secure practicable route. Many factors are to be considered in the safety and security risk analysis of routes, including rail traffic density, time and distance in transit, track class and conditions, environmentally-sensitive or significant areas, population density, emergency response capability, past incidents, availability of practicable alternatives, and other factors.

The U.S. Coast Guard issues regulations regarding the movement of barge shipments of spent nuclear fuel and high-level radioactive waste, including the use of particular facilities, waterways, and vessel and port security procedures. Handling regulations specific to spent nuclear fuel are found at 33 CFR Part 126. The Coast Guard also designates safety zones and security zones that may apply to a specific port, facility, or waterway, or may describe a zone of exclusion around a moving vessel (33 CFR Part 165). The DOE would meet or exceed these regulatory standards.

L.2.5 ADVANCE NOTIFICATION

As required by Section 180(b) of the NWPA, all shipments to a repository would abide by NRC regulations on advance notification of state and local governments. NRC regulations (10 CFR Part 73) provide for written notice to governors or their designees in advance of irradiated reactor fuel shipments through their states. The NRC regulations allow states to release certain advance information to local officials on a need-to-know basis. In 1998 DOE requested that the NRC amend its regulations to permit notification to tribal authorities in addition to states. This would enable the Office of Civilian Radioactive Waste Management to provide advance notification to tribes of repository shipments, consistent with current DOE policies and practices for other types of radioactive shipments that are not subject to the NWPA.

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. Notification of shipments to a repository would be in accordance with NRC regulations in effect at that time.

In accordance with NRC regulations, DOE Manual 460.2-1, *Radioactive Material Transportation Practices Manual for Use with DOE O 460.2A* (DIRS 171934-DOE 2002, all) requires written notice to governors or their designees before shipment of spent nuclear fuel and high-level radioactive waste through their states in a manner consistent with the requirements, as applicable, of 10 CFR 71.97 and 73.37. If sent by regular mail, the notice must be postmarked at least seven days before the shipment enters the state; for messenger service, it must arrive four 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. In the event of a change in schedule that differs more than 6 hours from what was in the notification to the governor or designee, DOE would provide the state with the new schedule by telephone.

L.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.

L.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.

L.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 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 among 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 appendices 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.” 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-55-1, *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 L.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.

L.2.9 PROPOSED RAIL REGULATIONS

The Transportation Security Administration has proposed that freight rail carriers and certain facilities that handle hazardous materials be able to report, upon request, 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.

L.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.

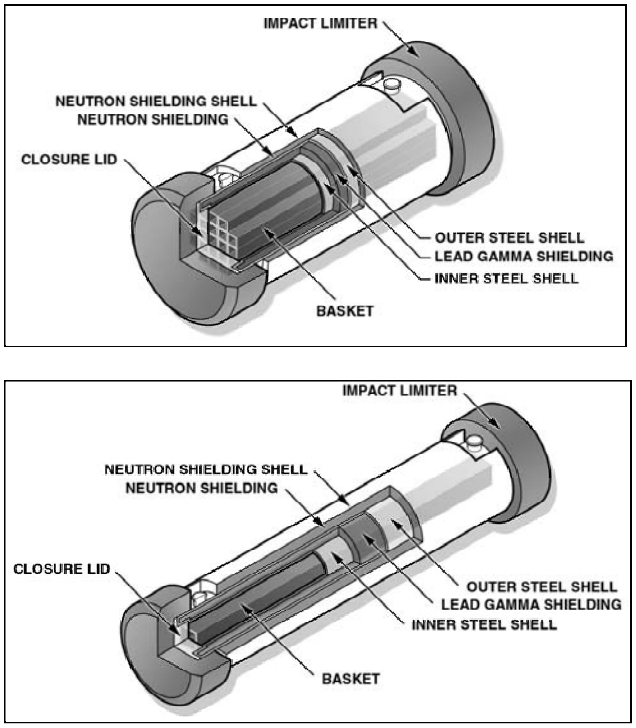

Figure L-3. Generic rail cask (a) and truck cask (b) for spent fuel.

L.3.1 TRANSPORTATION CASKS

Pursuant to Section 180(a) of the NWPA, all shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be in packages certified for such purposes by the NRC.

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 that 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 L-3 illustrates generic rail and truck casks.

L.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.

L.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.

L.3.4 CASK MAINTENANCE FACILITY

Transportation casks and the associated equipment (for example, personnel barriers and impact limiters) must be maintained in proper condition to satisfy the requirements in their NRC certificates of compliance. At the Cask Maintenance Facility, casks would periodically be removed from service for maintenance and inspection. The activities at the Cask Maintenance Facility would include but not be limited to testing, repairs, minor decontamination, and making approved modifications. The Cask Maintenance Facility would also serve as the primary recordkeeping facility for the cask fleet equipment.

L.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). 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. Not all origin sites of spent nuclear fuel and high-level radioactive waste have rail services. 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 railroad to transport casks from a Union Pacific mainline in Nevada to the repository site, and the Department would contract the operation and maintenance of the railroad.

L.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.

L.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 underway. During planning and actual transportation operations, stakeholders are and would continue to 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 Group committees and tribal governments, a national cooperative effort is underway as part of DOE's 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 will accommodate 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.

L.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 would be to identify a national suite of routes, both rail and highway. DOE is working with stakeholder groups in the process ofexamining potential routing criteria in the route identification process. State Regional Group committees, 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 continue to perform the work through a Topic Group of the Transportation External Coordination Working Group, and DOE intends to seek broader public input and collect comments on routing criteria and the process for development of a suite of routes. The process includes consideration of relevant regulations, industry practices, DOE requirements, and analysis of regional routes that states have previously evaluated in the process to identify a preliminary set of routes. DOE considers public involvement to be an essential element of a safe, efficient, and flexible transportation system.

L.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. The plans would include 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.

L.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 train service means 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.

L.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 railroad.

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.

L.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.

States and tribes may provide input on weather conditions, and specific transportation plans developed in the future may provide additional details on the input process. States and tribes may monitor the status of shipments using the satellite tracking system. 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.

L.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 L.2.7 addresses other training requirements),

L.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 L.2.5 addresses advance notification requirements. DOE and authorized 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. NRC regulations in 10 CFR Part 73 require that access to and disclosure of Safeguards Information be limited to those with an established need-to-know.

L.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 transportation 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-DOT 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.

In addition, the Interim Final Rule issued by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (71 FR 20752, April 16, 2008) requires that rail carriers shipping certain hazardous materials including Highway Route-Controlled Quantities of class 7 (radioactive) material, as defined by 49 CFR 173.403, conduct inspections of rail cars for signs of tampering or suspicious items.

L.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.

L.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.

L.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.

L.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 of similar casks, performing engineering analyses (such as computer-simulated tests), or by conducting scale-model or full-scale testing. As shown in Figure L-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 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.

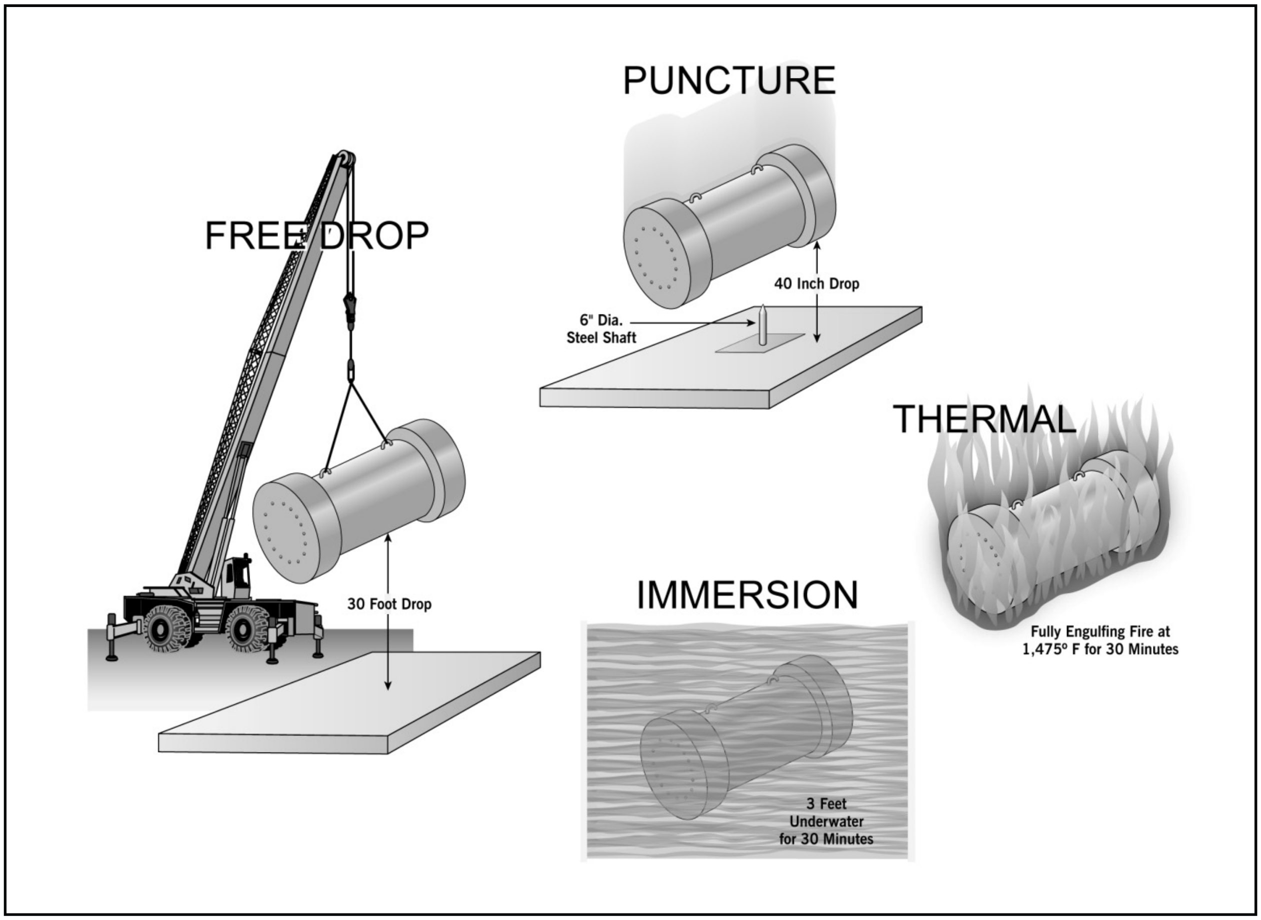

Figure L-4. Hypothetical accident conditions.

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.

L.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 145-kilometer (90-mile)-per-hour impact with a soft surface (such as tillable soil).

L.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.

L.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.

L.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 1,530 grams per square centimeter (21.7 pounds per square inch) to test for leakage. Furthermore, transportation casks for more than 1 million curies of radioactivity must be able to survive water pressure of about 20,400 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).

L.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.

L.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 the level of physical testing or analysis necessary for each cask design. Because the 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.

L.6 Emergency Response

L.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 L.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.

L.6.2 FEDERAL COORDINATION

The Department of Homeland Security coordinates the overall Federal Government response to radiological incidents that require a coordinated federal response in accordance with *Homeland Security Presidential Directive/HSPD-5* (DIRS 182271-DHS 2003, all) and the *National Response Framework* (DIRS 185500-DHS 2008, all). Based on Directive 5 criteria, an incident that would require a federal response 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 HSPD-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 HSPD-5 (DIRS 182271-DHS 2003, all), the President directed the development of the new *National Response Framework* (DIRS 185500-DHS 2008, 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, the departments 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 Framework* (DIRS 185500-DHS 2008, 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.

L.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 for training for public safety officials of appropriate units of local government and Indian tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste to a repository. Section 180(c) further provides that training must cover procedures for safe route transportation of these materials as well as for 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, DOE determined that is was timely to update its proposed policy for implementing Section 180(c).

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 Group committees and the Tribal 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. Based on consideration of these materials, DOE developed a revised proposed 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 program to test implementation of the Section 180(c) grant program prior to issuing the final Section 180(c) policy.

Pursuant to DOE’s proposed policy, Section 180(c) funds would be intended for training specific to shipments of spent nuclear fuel and high-level radioactive waste to a repository. DOE would work with states and tribes to evaluate current preparedness for safe routine transportation and emergency response capability and would provide funding as appropriate to ensure that state, tribal, and local officials are prepared for such shipments. Section 180(c) funds would be intended to supplement but not duplicate existing training for safe routine transportation and emergency preparedness. DOE would work with states and tribes to coordinate and integrate Section 180(c) activities with existing training programs designed for state, tribal, and local public safety officials. Subject to the availability of appropriated funds, DOE anticipates making two types of grants available to eligible states and tribes. An initial assessment and planning grant would be available approximately four years prior to the commencement of shipments through a state or tribe's jurisdiction to support assessing the need for and planning for training. Subsequently, DOE intends to issue training grants in each of the three years prior to a scheduled shipment through a state or tribe's jurisdiction and every year that shipments are scheduled. Since state and tribal governments have primary responsibility to protect the public health and safety in their jurisdictions, they would have flexibility to decide for which allowable activities to request Section 180(c) assistance to meet their unique needs. States and Tribes would be expected to coordinate with local public safety officials and to describe in their grant applications how the grants will be used to provide training to local public safety officials. The particular funding allocations would be determined in accordance with the approach in the proposed policy.

L.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 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 coordination 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.

L.9 Liability

The Price-Anderson Act (Section 170 of the Atomic Energy Act, as amended [42 U.S.C. 2011 *et seq.*]) 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.

L.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.

L.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.

L.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.

L.9.4 PRICE-ANDERSON ACT DEFINITION OF A NUCLEAR INCIDENT

A nuclear incident is any occurrence, including an extraordinary nuclear occurrence, causing bodily injury, sickness, disease, or death, or loss of or damage to property, or loss of use of property, arising out of or resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material (42 U.S.C. 2014).

L.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.

L.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.

L.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.

L.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. Sections 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.

L.9.9 INDEMNIFICATION FOR STATE, AMERICAN INDIAN, AND LOCAL GOVERNMENTS

State, American Indian tribes, 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.

L.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.

L.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.

L.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 would 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).

L.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).

L.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.

L.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 tribes, 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.

L.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 quote from the National Academy of Sciences findings and recommendations that are relevant to this Repository SEIS, followed by a discussion of the DOE position on or approach to the respective findings and recommendations.

L.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 a 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. In the Repository SEIS, DOE has evaluated the consequences of potential acts of sabotage or terrorism during the transport of spent nuclear fuel and high-level radioactive waste. 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, 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 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.

L.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 (that is, 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.

The Rail Alignment EIS evaluated the radiological risks of transportation accidents (Appendix K) 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 nuclear fuel. This administrative adjustment addresses some of the concerns of the Academy.

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. DOE is working with stakeholder groups in the process of examining potential routing criteria in the route identification process. State Regional Group committees, tribal governments, 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 recognizes the importance of open and effective public communication for a successful transportation program. DOE has proposed reviving the Communications Topic Group within the Transportation External Coordination Working Group to address how the Department can improve its communication methods on transportation of spent nuclear fuel and high-level radioactive waste to effectively manage perception of risk. DOE would proceed based on input from the Transportation External Coordination Working Group membership.

L.10.3 CURRENT CONCERNS ABOUT TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

L.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 L.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 such testing as the NRC requires.

L.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.

L.10.4 FUTURE CONCERNS FOR TRANSPORTATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

L.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 the Rail Alignment EIS, 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.

L.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.

DOE is working with stakeholder groups in the process of examining potential routing criteria in the route identification process. State Regional Group committees, 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 continue to perform the work through a Topic Group of the Transportation External Coordination Working Group, and DOE intends to seek broader public input and collect comments on routing criteria and the process for development of a suite of routes. The process includes consideration of relevant regulations, industry practices, DOE requirements, and analysis of regional routes that states have previously evaluated in the process to identify a preliminary set of routes. DOE considers public involvement to be an essential element of a safe, efficient, and flexible transportation system.

L.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 railcars, 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.

L.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.

L.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 for training for public safety officials of appropriate units of local government and Indian tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste to a repository. Section 180(c) further provides that training must cover procedures for safe routine transportation of these materials as well as for 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, DOE determined that it was timely to update its proposed policy for implementing Section 180(c).

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 Group committees and the Tribal 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. Based on consideration of these materials, DOE developed a revised proposed 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 program to test implementation of the Section 180(c) grant program prior to issuing the final Section 180(c) policy.

Pursuant to DOE's proposed policy, Section 180(c) funds would be intended for training specific to shipments of spent nuclear fuel and high-level radioactive waste to a repository. DOE would work with states and tribes to evaluate current preparedness for safe routine transportation and emergency response capability and would provide funding as appropriate to ensure that state, tribal, and local officials are prepared for such shipments. Section 180(c) funds would be intended to supplement but not duplicate existing training for safe routine transportation and emergency preparedness. DOE would work with states and tribes to coordinate and integrate Section 180(c) activities with existing training programs designed for state, tribal, and local public safety officials. Subject to the availability of appropriated funds, DOE anticipates making two types of grants available to eligible states and tribes. An initial assessment and planning grant would be available approximately four years prior to the commencement of shipments through a state or tribe's jurisdiction to support assessing the need for and planning for training. Subsequently, DOE intends to issue training grants in each of the three years prior to a scheduled shipment through a state or tribe's jurisdiction and every year that shipments are scheduled. Since state and tribal governments have primary responsibility to protect the public health and safety in their jurisdictions, they would have flexibility to decide for which allowable activities to request Section 180(c) assistance to meet their unique needs. States and Tribes would be expected to coordinate with local public safety officials and to describe in their grant applications how the grants will be used to provide training to local public safety officials. The particular funding allocations would be determined in accordance with the approach in the proposed policy.

L.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 site and through the Transportation External Coordination Working Group web page. These two mechanisms allow program information that should be shared reach a broad audience.

L.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 (DIRS 182032-National Research Council 2006, 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.

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APPENDIX M

CULTURAL RESOURCES PROGRAMMATIC AGREEMENT

QA:N/A

MOL.20060531.0087

PROGRAMMATIC AGREEMENT
AMONG
THE U.S. DEPARTMENT OF INTERIOR BUREAU OF LAND MANAGEMENT, NEVADA (BLM);
THE U.S. DEPARTMENT OF ENERGY (DOE);
SURFACE TRANSPORTATION BOARD (STB);
AND
THE NEVADA STATE HISTORIC PRESERVATION OFFICE (SHPO)
REGARDING THE NEVADA RAIL PROJECT (NRP)

WHEREAS, Congress directed the United States Department of Energy (DOE) to characterize and evaluate the suitability of Yucca Mountain as a potential site for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste, and if appropriate, construct and operate the facility; and

WHEREAS, on July 23, 2002, the President signed into law (PL107–200) a joint resolution of the U.S. House of Representatives and the U.S. Senate designating the Yucca Mountain site in Nye County, Nevada, for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste; and

WHEREAS, in the event the Nuclear Regulatory Commission authorizes construction of the repository and receipt and possession of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, DOE would be responsible for transporting these materials to the Yucca Mountain Repository as part of its obligations under the Nuclear Waste Policy Act; and

WHEREAS, on April 8, 2004, DOE selected the mostly rail transportation scenario analyzed 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," as the transportation mode both on a national basis and in the State of Nevada; and

WHEREAS, on April 8, 2004, DOE selected the Caliente rail corridor in which to examine potential alignments for construction of a rail line; and

WHEREAS, the BLM and DOE have determined that the proposed NRP in Southern Nevada may have an effect upon properties eligible for inclusion in the National Register of Historic Places (NRHP), and have consulted with the Nevada SHPO pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended (NHPA); and

WHEREAS, BLM may issue a rail line right-of-way for the NRP across BLM managed lands; and

WHEREAS, this Programmatic Agreement (PA) covers all aspects of the planning, construction, and operation of the NRP, including but not limited to the rail alignment, sidings, staging area, borrow, ballast, or quarry pits, access roads, the construction zone, extra work areas, and all ancillary facilities;

WHEREAS, the Advisory Council on Historic Preservation was offered the opportunity to participate as a consulting party to this Agreement and declined; and

NOW THEREFORE, the consulting parties agree that construction of the NRP shall be administered in accordance with the following stipulations to ensure that historic properties will be treated to avoid or mitigate effects to the extent practicable, regardless of surface ownership, and to satisfy DOE and BLM Section 106 responsibilities for all aspects of the undertaking.

I. ROLES AND RESPONSIBILITIES

The consulting parties: BLM; SHPO; STB; and DOE, agree that DOE will be the Lead Federal Agency for implementing this PA. The consulting parties agree that the consultation and compliance portions of the current *BLM/SHPO Statewide Protocol* will be used to implement this PA (Appendix E, State Protocol Agreement as amended through January 2005). The relevant portions of that protocol are incorporated by reference.

DOE, in consultation with BLM, is responsible for administering this PA. This includes but is not limited to: ensuring that the consulting parties carry out their responsibilities; overseeing all cultural resource work; assembling all submissions to the SHPO, including reports, determinations of eligibility and effect, and treatment or data recovery plans; and for seeking SHPO concurrence with all agency compliance decisions. Stipulation E.9 delegates BLM lead responsibilities to the Ely Field Office (EFO) authorized officer.

DOE will be responsible for reviewing reports and making determinations of eligibility, developing treatment options, and determining effects of the NRP on private land. BLM will be responsible for reviewing reports and making determinations of eligibility, developing treatment options, and determining effects of the NRP on public land.

II. AREA OF POTENTIAL EFFECT

The Area of Potential Effect (APE) shall be defined to include all potential direct and indirect effects to cultural resources and properties of traditional religious and cultural importance from any activities associated with the undertaking, regardless of land ownership.

The proposed rail alignment, and all access roads and work areas or other facilities for this project located outside the rail alignment, will be managed according to the provisions of this PA. The APE for the rail line will be 200 feet from the center line of the alignment or the actual ROW application submitted to BLM, whichever is greater. The APE for access roads outside of the alignment will be a minimum of 100 feet wide with at least 50 feet on either side of centerline. The minimum APE for any construction areas or other temporary use areas, outside of the alignment, will be the footprint of the area plus 100 feet outward in all directions from the perimeter of each area. The APE for assessing indirect effects on historic properties outside of the rail line alignment will extend at least one mile in all directions from the perimeter of the direct effects APE.

DOE, in coordination with BLM, may amend the APE as needed, or as requested by the SHPO, by amending this PA under the provisions of Section J. The initial study area is described and presented in Appendix A.

STIPULATIONS

DOE, in cooperation with the other consulting parties, shall ensure that the following stipulations are carried out:

A. Identification

1. DOE funds all appropriate cultural resource identification activities (Appendix D), including inventory, records research, informant interviews, archaeological, historic, or ethnographic report preparation, monitoring, and curation based on the APE for all activity areas, or portions thereof, in a manner consistent with the BLM/SHPO Statewide Protocol.

2. Each consulting party (DOE, BLM, and SHPO) will identify interested persons and tribes to DOE. Upon concurrence from the consulting parties, DOE will involve identified interested persons, tribes, or affected ethnic groups in all activities associated with the undertaking, as appropriate.

3. Required identification activities shall be completed regardless of the ownership (federal or private) of the lands involved, and DOE shall be responsible for gaining access to privately held lands by applying all reasonable means available including obtaining right of entry through courts.

4. Previously recorded sites will be updated using the Nevada IMACS site form. Sites recorded ten years previously will be re-evaluated for National Register significance.

5. In cooperation with the BLM, DOE, in accordance with the *American Indian and Alaska Native Tribal Government Policy* (DOE, 2000), shall make a good faith effort to consult with tribes and identified interested persons, or affected ethnic groups, to identify properties of traditional religious and cultural importance, and to inform the consulting parties of their eligibility and suggest appropriate treatment to avoid adverse effects to historic properties in accordance with the consultation procedures as specified in Appendix C.

6. Prior to initiating identification efforts, the consulting parties, including DOE and its cultural resource consultants, the BLM State Office, all appropriate BLM field Offices and the SHPO, will meet to finalize identification efforts, including the treatment of isolates, historic mining complexes, and linear resources. The results of those meetings which materially affect the nature of this Agreement are automatically appended to this Agreement.

B. Eligibility

1. DOE on private land, BLM on public land, and in consultation with SHPO, shall evaluate all cultural resources located within the APE for eligibility to the NRHP. Eligibility will be determined prior to the initiation of activities, within a construction segment, that may affect cultural resources. Eligibility will be determined in a manner compatible with the BLM/SHPO Statewide Protocol.

2. DOE, in consultation with BLM and SHPO, shall consult with appropriate tribes to evaluate the eligibility of properties of traditional religious and cultural importance. Consultation procedures are specified in Appendix C.

3. To the extent practicable, eligibility determinations shall be based on inventory information. If the information gathered in the inventory is inadequate to determine eligibility, DOE, through its cultural resource consultants, shall conduct limited subsurface testing or other evaluative techniques to determine eligibility.

   As needed, DOE, in consultation with the other consulting parties, will develop testing plans and submit them to the SHPO for concurrence. DOE shall provide identified tribes and interested parties with the same review opportunity as afforded the SHPO. Any proposed testing shall be limited to disturbing no more than 25 percent of the surface area of the resource being evaluated.

4. If any of the consulting parties, identified tribe or interested parties disagree regarding eligibility, DOE shall notify all consulting parties of the dispute and seek to resolve it among the parties. If the dispute cannot be resolved, DOE shall seek a formal determination of eligibility from the *Keeper of the National Register*. The Keeper will take 45 calendar days to make a determination or request additional information. The Keeper's determination will be considered final.

C. Treatment

1. In avoiding or mitigating effects, DOE on private land, BLM on public land and in consultation with SHPO, shall determine the precise nature of effects to historic properties identified in the APE. DOE, in consultation with BLM, shall develop a comprehensive treatment or data recovery plan and seek SHPO concurrence on the consolidated plan. At the same time, DOE shall provide identified tribes and interested parties with the same review timeframe as afforded the SHPO.

2. To the extent practicable, the consulting parties shall ensure that DOE avoids effects to historic properties through project design, or redesign, relocation of facilities, or by other means in a manner consistent with the BLM/SHPO Statewide Protocol. When avoidance is not practical, DOE, in consultation with the consulting parties, identified interested persons, and appropriate tribes, shall ensure that an appropriate Treatment or Data Recovery Plan designed to lessen or mitigate project-related effects to historic properties is developed and implemented.

3. For properties eligible under Criteria (a) through (c), mitigation other than data recovery may be considered in the Treatment Plan (e.g., Historic American Buildings Survey/Historic American Engineering recordation, oral history, historic markers, exhibits, interpretive brochures or publications, etc.). Where appropriate, Treatment Plans shall include provisions (content and number of copies) for a publication for the general public.

4. When data recovery is proposed, DOE, in consultation with BLM and SHPO, shall ensure that a Data Recovery Plan is developed and implemented that is consistent with the Secretary of the Interior's *Standards and Guidelines for Archaeology and Historic Preservation* (48 FR 44716), and *Treatment of Historic Properties: A Handbook* (Advisory Council on Historic Preservation 1980).

5. DOE, through its cultural resource consultants, shall implement and complete the fieldwork portions of any final Treatment or Data Recovery Plan prior to initiating any activities in any construction segment (Stipulation G) that may affect historic properties located within the area covered by the plan.

6. DOE shall ensure that all records and materials resulting from identification and treatment efforts are curated in accordance with 36 CFR 79 in a BLM-approved facility in Nevada. Materials covered by Native American Graves Protection and Repatriation Act (NAGPRA) will be handled in accordance with 43 CFR 10. All materials collected will be maintained in accordance with 36 CFR 79 or 43 CFR 10 until the final treatment report is complete and collections are curated or returned to their owners. DOE will encourage private owners to donate collections from their lands to an appropriate curation facility.

7. DOE shall ensure that all final archaeological reports resulting from actions pursuant to this PA will be provided to the consulting parties, tribes and other interested persons. All such reports shall be consistent with contemporary professional standards and the Secretary of the Interior's Standards for *Final Reports of Data Recovery Programs* (48 FR 44716-44740).

8. The consulting parties agree that visual impacts to landscapes or other historic properties that are mitigated to BLM Class II Visual Resource Management standards (substantially unnoticeable) shall be considered to have no adverse affect.

9. Any dispute concerning treatment will be resolved according to Stipulation I.

D. Discovery Situations

   1. Human Remains

      a. If anyone associated with the NRP encounters what appears to be human remains during construction or other project related activities, all activity will halt in the immediate vicinity of the discovery, and all project related activities will be kept at least 200 feet away from the discovery in all directions.

      b. The BLM, DOE, and SHPO will be notified of the find as soon as possible.

      c. The BLM shall notify its law enforcement staff, who will inform and work with local law enforcement and coroner, to determine if the human remains are associated with a crime.

d. Once it has been determined that the discovery is not the result of a crime scene, the BLM and DOE shall comply with the 43 CFR 10 on public land and Nevada Revised Statutes (NRS) 383 on private land.

2. Other Situations

a. Prior to initiating any activities within the APE, DOE will identify who will be responsible for notifying BLM of any discoveries. In addition to the stipulations here, the process detailed in Appendix B will be followed in all discovery situations, including human remains and other NAGPRA objects.

b. As soon as there is a discovery or unanticipated impact situation, all NRP related activities will halt in the immediate vicinity of the discovery. Once in a safe condition, activities would be directed away from an area at least 200 feet in all directions from the point of discovery. DOE will immediately notify BLM, the SHPO and other landowner as appropriate of the situation.

c. DOE shall notify the SHPO, BLM, tribes, and interested parties as appropriate within one working day of being notified of the discovery or unanticipated impact, and consider their initial comments on the situation. DOE will also initiate the procedures outlined in Appendix B. Within two working days after initial notification, the BLM for public lands, and DOE for private lands, shall notify all consulting parties, tribes, and interested parties, of the decision to either allow NRP activities to proceed or to require further evaluation or mitigation.

d. If, in consultation with the consulting parties, BLM determines that mitigation for discoveries or unanticipated impacts is required, DOE shall solicit comments from the consulting parties, tribes, and interested persons, as appropriate, to develop mitigating measures. The consulting parties, tribes, and interested persons, as appropriate, will be allowed two working days to provide DOE with comments to be considered when BLM or DOE, depending on land status, decides on the nature and extent of mitigative efforts. Within seven working days of initial notification, the BLM or DOE, depending on land status, will inform all consulting parties of the nature of the mitigation required, and ensure that such mitigative actions are implemented before allowing NRP activities to resume.

e. DOE, in consultation with BLM, may consider the following types of activities as categorical exclusions meaning SHPO consultations are not required:

1) Conducting non-archaeological data collection and monitoring activities, not associated with proposed undertakings, that involve new surface disturbance less than one square meter. Such activities include but are not limited to forage trend monitoring, stream gauges, weather gauges, research geophysical sensors, photoplots, traffic counters, animal traps, or other similar devices.
2) Installing facilities such as recreational, special designation, regulatory, or information signs, visitor registers, kiosks, cattle guards, gates, temporary corrals, or portable sanitation devices in previously disturbed areas outside of known historic properties.

    3) Decisions and enforcement actions (that do not involve cultural resources) to ensure compliance with laws, regulations, orders, and all other requirements imposed as conditions of approval, when the original approval was subject to the NHPA Section 106 process.

3. DOE shall ensure that reports of mitigation efforts for discovery situations are completed in a timely manner and conform to the Secretary of Interior's *Format Standards for Final Reports of Data Recovery Programs* (42 FR 5377-79). Drafts of such reports shall be submitted to the SHPO for review and comment as set forth in Stipulation H.2 of this PA.

4. Any disputes or objections arising during a discovery situation that cannot be resolved by DOE, BLM and SHPO shall be handled in accordance with Stipulation I.

5. NRP related activities in the area of the discovery will be halted on public land until DOE is notified by the BLM Authorized Officer in writing that mitigation is complete and activities can resume.

E. Other Considerations, including but not limited to

1. DOE shall ensure that all stipulations of this PA are carried out by BLM, SHPO, and all contractors, subcontractors, cultural resource consultants, or other personnel involved with this undertaking.

2. DOE shall ensure that ethnographic, historic, architectural, and archaeological work conducted pursuant to this PA is carried out by or under the direct supervision of persons meeting qualifications set forth in the Secretary of the Interior's *Professional Qualification Standards* dated June 20, 1997 (62 FR 33707-33723), which are part of the larger Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* (48 FR 44716) and who have been permitted for such work by the consulting parties.

3. DOE, in cooperation with BLM and SHPO, shall ensure that all its personnel and all the personnel of its contractors, subcontractors, and cultural resource consultants are trained and directed not to engage in the illegal collection of historic and prehistoric materials. DOE shall cooperate with the BLM to ensure compliance with the Archaeological Resources Protection Act of 1979 (16 U.S.C. 470) on Federal lands and with NRS 381 for private lands.

4. DOE shall bear the expense of identification, evaluation, monitoring and treatment of all cultural resources directly or indirectly affected by NRP-related activity. Such costs shall include, but not be limited to, pre-field planning, fieldwork, post-fieldwork analysis, research and report preparation, interim and summary report preparation, publications for the general public, and the cost of curating project documentation and artifact collections.

5. Identification, evaluation, and treatment efforts may extend beyond the geographic limits of the APE when the resources being considered extend beyond the APE.

6. Properties of traditional religious and cultural importance will be identified, evaluated,

and treated through consultation with appropriate tribes or interested persons. DOE may contract for data gathering to assist in identifying, evaluating, and treating these properties. However, formal consultation, as needed, will be done by DOE in consultation with the other consulting parties. Identification, evaluation, and treatment efforts for properties of traditional religious and cultural importance shall be consistent with the BLM/SHPO Statewide Protocol and Appendix C.

7. Information on the location and nature of all cultural resources and will be made available consistent with the provisions of the Archaeological Resources Protection Act, the NHPA, and their associated implementing regulations. All information considered proprietary by tribes, will be held confidential by the consulting parties to the extent provided by Federal law.

8. DOE shall ensure that any human remains, grave goods, items of cultural patrimony, and sacred objects encountered during the undertaking are treated with the respect due such materials. In coordination with this PA, human remains and associated grave goods found on Federal land will be handled according to the provisions of the NAGPRA and its implementing regulations (43 CFR 10). Human remains and associated grave goods on private land will be handled according to the provisions of Nevada Revised Statutes NRS 383.

9. The lead and point of contact for BLM will be the EFO authorized officer. All DOE/SHPO activities will be coordinated through the EFO and all other BLM Field Offices (Las Vegas and Tonopah) will coordinate their determinations, comments, issues, and other matters through the EFO to ensure consistency among Field Offices. The EFO will consolidate all BLM comments and other communications into a single BLM communication. DOE will not interact with the BLM offices without explicit approval of the EFO. Any issues that cannot be resolved by the EFO will be referred to the BLM State Office for resolution.

F. Monitoring

1. Consulting parties may monitor actions carried out pursuant to this PA. To the extent practicable, all monitoring activities will be done so as to minimize the number of monitors involved in the undertaking.

2. Areas that DOE, in consultation with the SHPO, BLM, tribes, or interested party, identifies as sensitive historic properties or religiously or culturally important in a monitoring plan will be monitored by an appropriate professional or tribal representative during construction or operational activities that may impact the area. Monitors shall be empowered to stop work in the specific area of concern to protect resources and work will not proceed in identified sensitive areas without a monitor present.

G. Notices to Proceed

After compliance with Stipulation A.3, the BLM, in consultation with the other consulting parties may issue Notices to Proceed to DOE for individual construction segments, as defined by the Treatment Plan, which includes the approach for effects mitigation, under any of the following conditions:

1. DOE, BLM and SHPO have determined that there are no cultural resources within the APE for the construction segment; or
2. DOE, BLM and SHPO have determined that there are no historic properties within the APE for the construction segment; or
3. DOE, after consultation with the BLM, SHPO, tribes, and interested persons has implemented an adequate Treatment Plan for the construction segment, and
    a. The fieldwork phase of the treatment option has been completed; and
    b. DOE and BLM have accepted a letter summary description of the fieldwork performed and a reporting schedule for that work.

H. Time Frames

1. Reports: BLM, shall review and comment on any report submitted by DOE within 30 calendar days of receipt. DOE will consolidate all comments and send them to SHPO as needed.
2. SHPO Consultation: After review by the other consulting parties, DOE shall submit the results of all identification, evaluation, and treatment efforts, including Treatment or Data Recovery Plans to the SHPO for a 30-calendar-day review and comment period.
3. Consultation with Tribes or Interested Parties: Concurrent with SHPO review, DOE shall submit the results of all identification and evaluation efforts, including discovery situations, and Treatment Plans to tribes and other identified interested persons for a 30-calendar-day review and comment period.
4. If any consulting party to this PA, tribe, or other interested person fails to respond to DOE within 30 calendar days of the receipt of a submission, DOE shall presume concurrence with the findings and recommendations as detailed in the submission and proceed accordingly.
5. Reports: A draft final report of all identification, evaluation, treatment or other mitigative activities will be due to the BLM from DOE within nine months after the completion of the fieldwork associated with the activity, unless otherwise negotiated. Negative inventories will be documented on BLM Negative Inventory Forms and sent to BLM and SHPO in a timely manner.
6. Curation: All reports, records, photographs, maps, field notes, artifacts, and other materials collected or developed for any identification, evaluation, or treatment activities will be curated in a facility in accordance with 36 CFR 79 approved by the consulting parties at the time the final report associated with that activity is accepted by DOE, unless materials and artifacts must be returned to the owner.

7. Discovery Situations: As specified in Stipulation D.

I. Dispute Resolution

1. Should any party to this PA object to any action carried out or proposed with respect to the implementation of this PA, DOE shall consult with the objecting party to resolve the objection. If after initiating such consultation DOE determines that the objection cannot be resolved through consultation, DOE shall forward all documentation relevant to the objection to the State Director of the Bureau of Land Management. Such documentation shall include DOE's proposed response to the objection, with the expectation that within 30 days after receipt of all pertinent documentation, the State Director shall:

    a. Advise DOE that the BLM concurs in DOE's proposed final decision, whereupon DOE will respond to the objection accordingly; or,

    b. Provide DOE with an alternative to resolve the objection.

    The BLM State Director's decision shall be considered final.

2. In consultation with DOE, any determination made by the BLM State Director will be understood to pertain only to the subject of the dispute. DOE's responsibility to carry out actions required by this PA that are not subject of the dispute shall remain unchanged.

J. Amendment

Any consulting party to this PA may request that this PA be amended, whereupon the consulting parties will consult to consider such amendment.

K. Termination

Any consulting party to this PA may terminate the PA by providing 30 calendar days' advance written notice with cause to the other consulting parties, provided that the consulting parties will consult during the period prior to termination to seek agreement on amendments or other actions that would avoid termination.

L. Execution

1. Execution and implementation of this PA evidences that the consulting parties have satisfied their Section 106 responsibilities for all actions associated with the construction and installation of the NRP.

2. In the event that this PA is terminated, DOE in cooperation with BLM, shall follow the requirements of 36 CFR800 for the management of historic properties.

3. This PA shall become effective on the date of the last signature below and shall remain in effect until terminated as provided in Stipulation K, or until undertaking is completed, or a maximum five (5) years from the effective date.

CONSULTING PARTIES:

BUREAU OF LAND MANAGEMENT

By: Ron Wenker Date: 3/10/06

Title: BLM Nevada State Director

CONSULTING PARTIES:

DEPARTMENT OF ENERGY

By: J Gary Lanthrum Date: 9 FEB 2006

Title: Director, Office of National Transportation

CONSULTING PARTIES:

NEVADA STATE HISTORIC PRESERVATION OFFICE

By: Alice M. Baldrica Date: 4/17/06

Title: Deputy Nevada State Historic Preservation Officer

CONSULTING PARTIES:

SURFACE TRANSPORTATION BOARD

By: Victoria Rutson Date: Feb. 8, 2006

Title: Chief, Section of Environmental Analysis

APPENDIX N

DISTRIBUTION LIST

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APPENDIX N

DISTRIBUTION LIST

The U.S. Department of Energy (DOE) is providing copies of the Nevada Rail Corridor SEIS and Rail Alignment EIS 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. DOE will provide copies to other interested organizations or individuals on request.

N.1 United States Congress

N.1.1 UNITED STATES SENATORS FROM NEVADA

The Honorable John E. Ensign
U.S. Senator
United States Senate

The Honorable Harry Reid
Senate Majority Leader
United States Senate

N.1.2 UNITED STATES REPRESENTATIVES FROM NEVADA

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U.S. House of Representatives

The Honorable Jon C. Porter, Sr.
3rd District Representative
U.S. House of Representatives

The Honorable Dean A. Heller
2nd District Representative
U.S. House of Representatives

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Chairman Senate Committee on Energy & Natural Resources

The Honorable Thad Cochran
Ranking Member Senate Committee on Appropriations

The Honorable James Inhofe
Ranking Member Senate Committee on Environment & Public Works

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Senate Committee on Commerce, Science & Transportation
Subcommittee on Surface Transportation & Merchant Marine

The Honorable Trent Lott
Senate Committee on Commerce, Science & Transportation
Subcommittee on Surface Transportation & Merchant Marine Infrastructure, Safety & Security

The Honorable Ted Stevens
Vice Chairman
Senate Committee on Commerce, Science & Transportation

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The Honorable David Obey
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The Honorable Peter J. Visclosky
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Subcommittee on Energy & Water Development

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Ranking Member
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Chairman
House Committee on Armed Service

N.2 Federal Agencies

Dr. Mark Abkowitz
U.S. Nuclear Waste Technical Review Board

Dr. William Howard Arnold
U.S. Nuclear Waste Technical Review Board

Dr. Thure Cerling
U.S. Nuclear Waste Technical Review Board

Dr. David Duquette
U.S. Nuclear Waste Technical Review Board

Dr. B. John Garrick
Chairman
U.S. Nuclear Waste Technical Review Board

Dr. George Milton Hornberger
U.S. Nuclear Waste Technical Review Board

Dr. Andrew C. Kadak
U.S. Nuclear Waste Technical Review Board

Dr. Ronald Latanision
U.S. Nuclear Waste Technical Review Board

Dr. Ali Mosleh
U.S. Nuclear Waste Technical Review Board

Mr.William M. Murphy, Ph.D.
U.S. Nuclear Waste Technical Review Board

Dr. Henry Petroski
U.S. Nuclear Waste Technical Review Board

Ms. Dana Allen
U.S. Environmental Protection Agency
Region 8

Mr. William Arguto
U.S. Environmental Protection Agency
NEPA/Federal Facility
EPA Region 3

Ms. Susan Bromm
NEPA Compliance Division
U.S. Environmental Protection Agency

Mr. Ray Clark
U.S. Environmental Protection Agency - HQ

Mr. Joe Cothern
NEPA Coordination Team Leader
U.S. Environmental Protection Agency
EPA Region 7

Ms. Ann McPherson
Acting Manager
U.S. Environmental Protection Agency
EPA Region 9

Ms. Elizabeth Cotsworth
Director
U.S. Environmental Protection Agency
Office of Radiation & Indoor Air

Mr. Kenneth Czyscinski
U.S. Environmental Protection
Agency/ORIA/RPD

Dr. Richard Graham
Department of Energy Reviewer
U.S. Environmental Protection Agency
Office of Ecosystem Protection & Remediation
NEPA Program

Mr. Robert Hargrove
Chief, Strategic Planning and Multimedia Programs
U.S. Environmental Protection Agency
Region 2

Mr. James Havard
U.S. Environmental Protection Agency - HQ

Ms. Elizabeth Higgins
Director, Office of Environmental Review
U.S. Environmental Protection Agency
Regional Administrator’s Office
Region 1

Mr. David Huber
U.S. Environmental Protection Agency - HQ

Mr. Michael P. Jansky
Regional Environmental Review Coordinator
U.S. Environmental Protection Agency
EPA Region 6

Ms. Anne Norton Miller
Director, Office of Federal Activities
U.S. Environmental Protection Agency

Mr. Heinz Mueller
Chief of NEPA Program Office
U.S. Environmental Protection Agency
EPA Region 4

Ms. Grace Musumeci
Chief, Environmental Review Section
U.S. Environmental Protection Agency
EPA Region 2

Mr. Dennis O’Connor
U.S. Environmental Protection Agency

Ms. Christine Reichgott
Manager, NEPA Review Unit
U.S. Environmental Protection Agency
EPA Region 10
Office of Ecosystems, Tribal, & Public Affairs

Ms. Marthea Rountree
U.S. Environmental Protection Agency
Office of Federal Activities

Mr. Bill Ryan
U.S. Environmental Protection Agency
Office of Ecosystems & Communities

Mr. David P. Schmidt
Department of Energy Reviewer
U.S. Environmental Protection Agency
Environmental Review Office

Mr. Larry Svoboda
Director, NEPA Program
U.S. Environmental Protection Agency
EPA Region 8
Office of Ecosystem Protection & Remediation

Mr. Timothy L. Timmermann
Environmental Scientist
U.S. Environmental Protection Agency
Office of Environmental Review
EPA Region 1

Mr. Ken Westlake
Chief, Environmental Planning & Evaluation Branch
U.S. Environmental Protection Agency
Region 5

Ms. Catherine M. Bohan
NEPA Compliance Officer
U.S. Department of Energy
West Valley Demonstration Project

Mr. Gerald G. Boyd
Director
U.S. Department of Energy
Oak Ridge Operations Office

Mr. David A. Brockman, Manager
U.S. Department of Energy
Richland Operations Office

Mr. Gary Burch
Director
Central Regional Office
U.S. Department of Energy

Mr. Jack Depperschmidt
NEPA Compliance Officer
U.S. Department of Energy
Idaho Operations Office

Mr. Drew Grainger
NEPA Compliance Officer
U.S. Department of Energy
Savannah River Operations Office

Ms. Susan Houghton
Director, Communications & Public Affairs
Lawrence Livermore National Laboratory
Public Affairs Office

Mr. Paul M. Kesich
Environmental Protection Group Manager
Fermi National Accelerator Laboratory

Ms. Tracy Loughead
Director, Office of Public Affairs
National Nuclear Security Administration
Service Center
Kirtland Air Force Base East

Ms. Marge Lynch
Assistant Laboratory Director
Brookhaven National Laboratory
Community Education, Government & Public Affairs

Ms. Aundra M. Richards
Berkeley Site Office
U.S. Department of Energy

M. Nancy N. Sanchez
Stanford Site Office Director
U.S. Department of Energy

Ms. Elizabeth D. Sellers
Manager
U.S. Department of Energy
Idaho Operations Office

Mr. Gerald L. Talbot Jr.
Manager
U.S. Department of Energy
Nevada Site Office

Ms. Cindy Wilkinson
Deputy Director, Communications & Public Affairs
Argonne National Laboratory

Mr. Robert C. Wunderlich
Manager
U.S. Department of Energy
Chicago Operations Office

Mr. Alessandro Amaglio
Environmental and Historic Compliance Officer
Department of Homeland Security
FEMA Region IX

Mr. Bob Cox
Regional Environmental Officer
Department of Homeland Security
FEMA Region VIII

Mr. Mark Eberlein
Regional Environmental Officer
Department of Homeland Security
FEMA Region X

Mr. Donald Fairley
Regional Environmental Officer
Department of Homeland Security
FEMA Region VI

Ms. Catherine McManus
Regional Environmental Officer
Department of Homeland Security
FEMA Region III

Mr. Kevin Merli
Federal Insurance & Mitigation Division
Director
Department of Homeland Security
FEMA Region I

Ms. Jeanne Millin
Regional Environmental Officer
Department of Homeland Security
FEMA Region V

Mr. David Reese
Department of Homeland Security
USM/Administrative Services/Safety &
Environmental Programs

Mr. Ken Sessa
Regional Environmental Officer
Department of Homeland Security
FEMA Region VII

Mr. Jack Sullivan
Regional Environmental Officer
Department of Homeland Security
FEMA Region I

Mr. Edward Wandelt
Chief, Environmental Management (CG-443)
Department of Homeland Security
U.S. Coast Guard Headquarters

Mr. Brian Amme
Planning and Environmental Coordinator
U.S. Bureau of Land Management
Nevada State Office
Division of Natural Resources & Planning

Mr. Allen Anspach
U.S. Department of the Interior
Bureau of Indian Affairs

Ms. Pamela A. Bergmann
Regional Environmental Officer
U.S. Department of the Interior

Mr. Steve Brown
Branch Chief, National Resources
Bureau of Indian Affairs
Western Nevada Agency

Mr. Bill Dunkelberger
Field Office Manager
U.S. Bureau of Land Management
Bishop Field Office CA-170

Mr. William S. Fisher
Field Station Manager
U.S. Bureau of Land Management
Tonopah Field Station

Mr. Peter Graves
Resources Management Specialist
U.S. Bureau of Land Management
Ridgecrest Field Office CA-650

Ms. Helen M. Hankins
Field Office Manager
U.S. Bureau of Land Management
Elko Field Office

Ms. Amy Heuslein
U.S. Bureau of Indian Affairs
Western Regional Office
Environmental Quality Services

Mr. George Meckfessel
Planning and Environmental Coordinator
U.S. Bureau of Land Management
Needles Field Office CA-690

Mr. John "Jack" S. Mills
Environmental Coordinator
U.S. Bureau of Land Management
California State Office

Mr. Mark T. Morse
Field Office Manager
U.S. Bureau of Land Management
Las Vegas Field Office

Mr. Richard Orr
Assistant Field Manager
U.S. Bureau of Land Management
Caliente Field Station

Ms. Patricia S. Port
Regional Environmental Officer
U.S. Department of the Interior

Mr. Andrew L. Raddant
Regional Environmental Officer
U.S. Department of the Interior

Mr. Timothy M. Read
Field Manager
U.S. Bureau of Land Management
Barstow Field Office CA-680

Mr. Terry Reed
Field Office Manager
U.S. Bureau of Land Management
Winnemucca Field Office

Mr. James T. Reynolds
Superintendent
U.S. Department of the Interior
National Park Service

Mr. John Runs
Field Office Manager
U.S. Bureau of Land Management
Ely Field Office

Mr. John O. Singlaub
Field Office Manager
U.S. Bureau of Land Management
Carson City Field Office

Mr. Gerald Smith
Field Office Manager
U.S. Bureau of Land Management
Battle Mountain Field Office

Mr. Preston Sleeger
Regional Environmental Officer
U.S. Department of the Interior

Mr. Michael Soukup
Associate Director
U.S. Department of the Interior
National Park Service
Natural Resource Stewardship & Science

Mr. Robert F. Stewart
Regional Environmental Officer
U.S. Department of the Interior

Mr. Willie R. Taylor
Director, Office of Environmental Policy and Compliance
U.S. Department of the Interior

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards
Division of Waste Management & Environmental Protection

Mr. E. William Brach
Director, Spent Fuel Project Office
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards

Mr. David J. Brooks
U.S. Nuclear Regulatory Commission
Division of Waste Management

Ms. Cynthia Carpenter
Chief, Generic Issues and Environmental Projects
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
ATTN: Document Control Desk

Mr. Thomas H. Essig
Chief, Environmental & Performance Assessment Branch
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards
Waste Management Division

Mr. James R. Firth
U.S. Nuclear Regulatory Commission
Division of Waste Management

Mr. Scott C. Flanders
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards
Division of Waste Management & Environmental Protection

Mr. Robert J. Frazier
U.S. Department of Veterans Affairs
Office of Construction and Facilities Management

Mr. Brian Holian
Director, License Renewal & Environmental Impacts Programs
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

Ms. Elaine M. Keegan
U.S. Nuclear Regulatory Commission
Spent Fuel Project Office, MS 013D13

Dr. Janet P. Kotra
U.S. Nuclear Regulatory Commission

Mr. Andrew J. Kugler
Chief, Environmental Section
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

Mr. Richard K. Major
U.S. Nuclear Regulatory Commission
Advisory Committee on Nuclear Waste

Mr. David B. Matthews
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

Mr. Keith I. McConnell
U.S. Nuclear Regulatory Commission

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Director of the Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

Mr. William C. Reamer
U.S. Nuclear Regulatory Commission
Division of Waste Management

Mr. Tyson Smith
U.S. Nuclear Regulatory Commission
Office of the General Counsel

Mr. Blair Spitzberg
U.S. Nuclear Regulatory Commission
Region IV

Mr. Newton King Stablein
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards
High Level Waste & Uranium Recovery

Mr. Martin Virgilio
Deputy Executive Director for Materials, Research & State Programs
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety & Safeguards

Mr. Jack Bush
U.S. Department of Defense
Office of the Civil Engineer, Bases & Units Branch
Headquarters, U.S. Air Force/ILEPB

Mr. Thomas M. Griffith
Naval Reactors, Naval Sea Systems Command
U.S. Department of the Navy

Ms. Mary Hassell
Head, Natural Resources Section (LFL-1)
U.S. Department of Defense
Headquarters, U.S. Marine Corps

Mr. Fred W. Kuhn
Deputy Assistant Secretary
Department of the Air Force

Ms. Lynn Murphy
Environmental Planning Coordinator
U.S. Department of Defense
Naval Facilities Engineering Command
Southwest Division Code EVP.DT

Lt. Colonel Rich Zibearth
Acting Director
USAF/DOE Liaison Office

Mr. Carl Bausch
Director, Office of Human & Natural Environment (TPE-30)
U.S. Department of Transportation
Federal Transit Administration

Mr. Christopher Calamita
Attorney-Advisor
U.S. Department of Transportation
National Highway Traffic Safety Administration (NCC-112)

Mr. Michael Calhoun
U.S. Department of Transportation
Federal Railroad Administration

Mr. Richard Corley
Environmental Program Manager
U.S. Department of Transportation
Maritime Administration

Mr. Stephen Grimm
U.S. Department of Transportation
Federal Railroad Administration

Dr. Robert A. McGuire
Associate Administrator Hazardous Materials Safety, DHM1
U.S. Department of Transportation
Research & Special Programs Administration

Mr. Matthew McMillen
U.S. Department of Transportation
Federal Aviation Administration
Office of Environment & Energy

Ms. Camille Mittelholtz
Environmental Team Leader
U.S. Department of Transportation
Office of Transportation Policy

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Surface Transportation Board

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U.S. Department of Transportation
Hazardous Material Division

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U.S. Department of Transportation
Headquarters, Federal Highway Administration

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Director, Division of Real Property
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Office for Facilities Management & Policy

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U.S. Department of Health & Human Services
Centers for Disease Control & Prevention

Mr. Eric Benderson
Associate General Counsel for Litigation
U.S. Small Business Administration
Office of Litigation

Mr. Michael Campilongo
Attorney Advisor
U.S. Small Business Administration
Office of the Ombudsman

Mr. David A. Bergsten
U.S. Department of Agriculture
Animal & Plant Health Inspection Service

Ms. Andree DuVarney
National Environmental Coordinator, Ecological Sciences Division
U.S. Department of Agriculture
Natural Resources Conservation Service

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Division Secretary, Resource & Economics Division
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Economic Research Service

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U.S. Department of Agriculture
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U.S. Department of Agriculture
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U.S. Department of Agriculture
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Dr. Joseph Wysocki
National Program Leader, Housing & Indoor Environment
U.S. Department of Agriculture
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National Science Foundation

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Susquehanna River Basin Commission

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Executive Director
Delaware River Basin Commission

Mr. Kevin Crowley
Director, Board on Radioactive Waste Management
The National Academies

Ms. Michelle DeGrandi
U.S. Department of Veterans Affairs
Office of General Counsel

Mr. James F. Devine
Senior Advisor For Science Applications
U.S. Geological Survey
National Headquarters, M/S 106

Mr. Robert J. Frazier
Program Manager
U.S. Department of Veterans Affairs
Office of Facilities Management

Mr. Michael Gosliner
General Counsel
Marine Mammal Commission

Mr. Jack Haugrud
Chief, Natural Resources Section
U.S. Department of Justice
Environmental & Natural Resources Division

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Agency Environmental Coordinator
U.S. Agency for International Development

Ms. Cherie Hutchison
Regulatory Specialist
U.S. Department of Labor
Mine Safety & Health Administration
Office of Standards, Regulations, & Variances

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Environmental Specialist
International Trade Commission

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National Capital Planning Commission
Urban Design & Plans Review Division

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National Oceanic & Atmospheric Administration

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National Aeronautics & Space Administration
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Director, Office of Outreach & Public Affairs
National Renewable Energy Laboratory

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Environment, Safety, & Health Division

Mr. John C. Matheson III
Senior Regulatory Review Scientist, Office of Surveillance & Compliance
U.S. Department of Health and Human Services
Food & Drug Administration Center for Veterinary Medicine

Frank Monteferrante, Ph.D.
U.S. Department of Commerce
Intergovernmental Affairs Division
Economic Development Administration

Dr. Charles P. Nicholson
Manager, NEPA Administration
Tennessee Valley Authority
Environmental Policy & Planning

Ms. Elizabeth Orlando
U.S. Department of State
Bureau of Oceans & International Environmental & Scientific Affairs

Mr. Brent Paul
Federal Environmental Officer
Federal Emergency Management Agency

Mr. Marcus Peacock
Program Associate Director
Office of Management & Budget
Natural Resource Division

Mr. John Pfeiffer
Office of Management & Budget
Energy, Science & Water Division

Mr. Celso Puente
U.S. Geological Survey
National Headquarters, M/S 423

Mr. Alfredo J. Riera
Principal Engineer, Engineering Department
International Boundary & Water Commission, U.S. & Mexico
U.S. Section

Mr. Mark Robinson
Director, Office of Energy Projects
Federal Energy Regulatory Commission

Mr. Lee Salviski
General Services Administration
Office of Applied Science

Mr. Andrew Thibadeau
Director, Division of Information Technology and Security
Defense Nuclear Facilities Safety Board

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Director, Office of Passenger Vessels & Information Processing
Federal Maritime Commission
Bureau of Consumer Complaints & Licensing

Dr. Gene Whitney
Executive Office of the President
Office of Science and Technology Policy

N.2.1 DEPARTMENT OF ENERGY ADVISORY BOARDS

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SSAB Administrator
Paducah Gaseous Diffusion Plant

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Chairman
Northern New Mexico Citizens' Advisory Board

Mr. Spencer Gross
Oak Ridge Site-Specific Advisory Board
SSAB Support Office

Mr. Ken Korkia
SSAB NEPA Point of Contact
Rocky Flats Citizens Advisory Board

Ms. Terri Lamb
Designated Federal Officer, Environmental Management Advisory Board

U.S. Department of Energy
Office of Environmental Management
EM-30.1/Forrestal Bldg.

Ms. Wendy Green Lowe
SSAB Facilitator
Idaho National Engineering & Environmental Lab Citizens Advisory Board

Ms. Menice Manzanares
CAB Administrator
Northern New Mexico Citizens' Advisory Board

Ms. Carla Sanda
SSAB Administrator
Community Advisory Board for Nevada Test Site Programs
c/o Stroller Navarro Joint Venture

N.3 State of Nevada

N.3.1 STATEWIDE OFFICES AND LEGISLATURE

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Governor of Nevada

The Honorable Mark E. Amodei
Senate President Pro Tempore
Nevada State Senate
Committee on High-Level Radioactive Waste

Kathy Besser
Chief of Staff
State of Nevada
Office of the Lieutenant Governor

The Honorable Barbara Buckley
Speaker
Nevada State Assembly

Ms. Holly Cheong
Environmental Planner II
Southern Nevada Water Authority – Resources

The Honorable Jerry Claborn
Vice Chairman, Natural Resources, Agriculture and Mining
Nevada State Assembly

The Honorable Catherine Cortez Masto
Attorney General of Nevada

Michael Dayton
Chief of Staff
Office of the Governor

Mr. Fred Dilger
Nevada Agency for Nuclear Projects

Mr. Steve Frishman
State of Nevada
Nuclear Waste Project Office

Mr. Pat Guinan
Legislative Counsel Bureau

Mr. Robert Halstead
Transportation Advisor
State of Nevada
Agency for Nuclear Projects

Mr. D. Bradford Hardenbrook
Supervisory Biologist - Habitat
Nevada Dept. of Wildlife

The Honorable Brian Krolicki
Lieutenant Governor of Nevada

The Honorable John Lee
Nevada State Senate
Committee on High-Level Radioactive Waste

Ms. Lisa Luptowitz
Environmental Planner II
Southern Nevada Water Authority – Resources

Mr. Stanley R. Marshall
Supervisor, Radiological Health Section
Nevada State Health Division
Bureau of Health Protection Services

The Honorable Mike McGinness
Vice-Chair, Committee on High-Level Radioactive Waste
Nevada State Senate

The Honorable Harvey J. Munford
Assemblyman
Nevada State Legislature

Mrs. Kim Perondi
Clearinghouse Coordinator
Nevada Dept. of Administration
Nevada State Clearinghouse

The Honorable William J. Raggio
Senate Majority Leader
Nevada State Senate
Committee on High-Level Radioactive Waste

The Honorable Dean A. Rhoads
Senate Majority Whip
Nevada State Senate

The Honorable Alice Constandina (Dina) Titus
Senate Minority Floor Leader
Nevada State Senate
Committee on High-Level Radioactive Waste

Gosia Sylwestrzak
Nevada Dept. of Administration

Mr. Robert R. Loux
Executive Director
Nevada Agency for Nuclear Projects

The Honorable Garn Mabey
Minority Leader
Nevada State Assembly

Mr. Arthur E. Mallory
Office of the District Attorney

The Honorable Harry Mortenson
Vice-Chair, Committee on High-Level
Radioactive Waste
Nevada State Assembly

Mr. James Pericola
Nevada Agency for Nuclear Projects

The Honorable Peggy Pierce
Nevada State Assembly
Committee on High-Level Nuclear Waste

Mr. Joseph C. Strolin
Administrator of Planning
Nevada Agency for Nuclear Projects

Ms. Melissa Subbotin
Press Secretary
Nevada Executive Office of the Governor

N.3.2 STATE AND LOCAL AGENCIES AND OFFICIALS

Ms. Catherine Barcomb
Administrator
Nevada Dept. of Conservation & Natural Resources
Commission for the Preservation of Wild Horses

Mr. Mike Baughman
Intertech Services Corporation

The Honorable Kenneth Benson
Chair
Eureka County Board of Commissioners

The Honorable Jim Bilyeu, Chair
Inyo County Board of Supervisors

Mr. Darin Bloyed
Chairman
Pershing County Board of Commissioners

The Honorable Nancy Boland, Chair
Esmeralda County Commission

The Honorable Susan Cash
Inyo County Board of Supervisors

The Honorable Robert A. Cashell, Sr.
Mayor
City of Reno

The Honorable Chuck Chapin, Vice Chair
Lander County Board of Commissioners
Nuclear Waste Liaison

Mr. Bob Cooper
Manager, Economic Development Dept.
City of Henderson

Mr. Ron Damele
Public Works Director
Eureka County Public Works

Mr. Bill Deist
County Administrator
Humboldt County

The Honorable Joni Eastley, Vice Chair
Nye County Board of Commissioners

The Honorable Clinton "Brent" Eldridge
Chair
White Pine County Commission

Mr. Bryan Elkins
Director, Community Development
City of Caliente

The Honorable Edward Fowler, Chair
Mineral County Board of Commissioners

Mr. Matt Gaffney, Project Coordinator
Yucca Mountain Repository Assessment Office
Inyo County

Mr. John Gervers
Latir Energy Consultants

Mr. Robert Hadfield
Interim Cty Manager
Lyon County

The Honorable Ronda Hammond-Hornbeck
Chair
Lincoln County Board of Commissioners

The Honorable Susan Holecheck
Mayor
City of Mesquite

The Honorable Gary Hollis, Chair
Nye County Board of Commissioners

Ms. Candice Jordan
Consultant
Lincoln County

Mr. Marc Jordan, Planning Manager
City of North Las Vegas
Development Dept.

Mr. Alan Kalt
Churchill County Comptroller

Mr. Aaron R. Kenneston
Washoe County Emergency Manager

Ms. Donna Kristaponis
County Manager
Lyon County

Mr. Clete Kus
Transportation Planner
City of North Las Vegas

Mr. Darrell Lacy, Director
Nye County Nuclear Waste Repository Project
Oversight Office

Mr. Robert List
Principal Consultant
The Robert List Company
Esmeralda County Repository Oversight
Program

The Honorable RaLeene Makley
White Pine County Commission

The Honorable Monte Martin
Fernley City Council

The Honorable Geno Martini
Mayor
City of Sparks

Mr. Rex Massey
Research and Consulting Services, Inc.

Ms. Linda Mathias
AUG Representative
Mineral County

Mr. Brian McKay
Chair
Nevada Commission on Nuclear Projects

The Honorable John H. Milton III
Chairman, Humboldt County Board of
Commissioners

Mr. Ed Mueller, Director
Esmeralda County Repository Oversight Program

Ms. Irene Navis, Planning Manager
Clark County Nuclear Waste Division

Ms. Maggie Plaster
Management Analyst
City of Las Vegas
City Manager's Office

The Honorable Kevin J. Phillips
Mayor
City of Caliente

The Honorable Wade Poulsen, Vice Chair
Board of Lincoln County Commissioners

The Honorable Rory Reid, Chair
Clark County Board of Commissioners

Mr. Ace Robison
Consultant

The Honorable Warren Russell
Elko County Board of Commissioners

Ms. Connie Simkins
Program Coordinator
Lincoln County Nuclear Waste Program

Mr. Mike Simon
White Pine County Nuclear Waste Project Office

Ms. Katy Singlaub
Washoe County Manager

The Honorable Bryan Sparks, Chair
Lander County Board of Commissioners

Mr. Robert K. Stokes
County Manager
Elko County

The Honorable Ken Tedford, Jr.
Mayor
City of Fallon

Mr. Engelbrecht von Tiesenhausen
Engineering Specialist
Clark County Nuclear Waste Division

The Honorable Roger Tobler
Mayor
City of Boulder City

Ms. Judy Treichel
Nevada Nuclear Waste Task Force

The Honorable Gwen Washburn, Chair
Churchill County Board of Commissioners

Mr. Pat Whitten
Director of Administration & Budgets
Story County Courthouse

Mr. Ron Williams
County Manager
Nye County

N.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 Haley Barbour
Governor of Mississippi

The Honorable Rod R. Blagojevich
Governor of Illinois

The Honorable Matt Blunt
Governor of Missouri

The Honorable Phil Bredesen
Governor of Tennessee

The Honorable Donald L. Carcieri
Governor of Rhode Island

The Honorable Felix Camacho
Governor of Guam

The Honorable Jon S. Corzine
Governor of New Jersey

The Honorable Charlie Crist
Governor of Florida

The Honorable Chet Culver
Governor of Iowa

The Honorable Mitch Daniels
Governor of Indiana

The Honorable James H. Douglas
Governor of Vermont

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 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 Timothy "Tim" M. Kaine
Governor of Virginia

The Honorable Linda Lingle
Governor of Hawaii

The Honorable John H. Lynch
Governor of New Hampshire

The Honorable Joe Manchin, III
Governor of West Virginia

The Honorable Ruth Ann Minner
Governor of Delaware

The Honorable Frank Murkowski
Governor of Alaska

The Honorable Janet Napolitano
Governor of Arizona

The Honorable Martin O'Malley
Governor of Maryland

The Honorable C. L. Butch Otter
Governor of Idaho

The Honorable Sarah H. Palin
Governor of Alaska

The Honorable David A. Paterson
Governor of New York

The Honorable Deval Patrick
Governor of Massachusetts

The Honorable Timothy Pawlenty
Governor of Minnesota

The Honorable Sonny Perdue
Governor of Georgia

The Honorable Rick Perry
Governor of Texas

The Honorable M. Jodi Rell
Governor of Connecticut

The Honorable Edward G. Rendell
Governor of Pennsylvania

The Honorable William “Bill” Richardson
Governor of New Mexico

The Honorable Robert “Bob” R. Riley
Governor of Alabama

The Honorable Bill Ritter, Jr.
Governor of Colorado

The Honorable Michael M. Rounds
Governor of South Dakota

The Honorable Mark Sanford
Governor of South Carolina

The Honorable Arnold Schwarzenegger
Governor of California

The Honorable Brian Schweitzer
Governor of Montana

The Honorable Kathleen Sebelius
Governor of Kansas

The Honorable Ted Strickland
Governor of Ohio

The Honorable Togiola Tulafono
Governor of American Samoa

N.5 Native American Tribes and Organizations

Mr. Kenny Anderson
Tribal Representative
Las Vegas Paiute Tribe

The Honorable Richard Arnold
Chairman
Pahrump Paiute Tribe

The Honorable John Azbil, Sr.
President
Round Valley Indian Tribal Council

Ms. Sandra Barela
Tribal Representative
Ely Shoshone Tribe

The Honorable John A. Barrett
Chairman
Citizens Band of Potawatomi (OK)

The Honorable Eleanor Baxter
Chairwoman
Omaha Tribe of Nebraska

The Honorable Homer Bear, Jr.
Chairman
Sac & Fox Tribal of the Mississippi in Iowa

The Honorable Audrey Bennett
President
Prairie Island Indian Community in the State of Minnesota

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 Dennis Bill
Chairman
Yomba Shoshone Tribe

Dr. Bonnie Eberhardt Bobb
Tribal Representative
Yomba Shoshone Tribe

The Honorable Claudia Brundin
Chairwoman
Blue Lake Racheria Indian Tribe

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 Fred Cantu
Chief
Saginaw-Chippewa Indian Tribe

The Honorable Delia Carlyle
Chairwoman
Ak Chin Indian Community Council

Mr. Jerry Charles
Tribal Representative
Ely Shoshone Tribe

Mr. Lee Chavez
Tribal Representative
Bishop Paiute Indian Tribe

Mr. David Conrad
Executive Director
National Tribal Environmental Council (NTEC)

Mr. Vince Conway
Tribal Chairman
Yerington Paiute Tribe

The Honorable Sherry Cordova
Chairwoman
Cocopah Tribe of Arizona

Ms. Betty L. Cornelius
Tribal Representative
Colorado River Indian Tribes

The Honorable Darrin Daboda
Chairman
Moapa Band of Paiute Indians

The Honorable Carl Dahlberg
Chairman
Fort Independence Indian Tribe

Ms. Darlene Dewey
Tribal Representative
Yomba Shoshone Tribe

Ms. Brenda Drye
Tribal Representative
Kaibab Band of Southern Paiutes

Ms. Barbara Durham
Tribal Representative
Timbisha Shoshone Tribe

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

Mr. Atef Elzeftawy
Tribal Representative
Las Vegas Paiute Tribe

Mr. Ron Escobar
Tribal Representative
Chemehuevi Tribe

Ms. Pauline Esteves
Tribal Representative
Timbisha Shoshone Tribe

The Honorable John Feliz, Jr.
Chair
Coyote Valley Band of Pomo Indians of
California

The Honorable Darrell Flyingman
Chairman
Cheyenne-Arapaho Tribes of Oklahoma

Mr. Maurice Frank-Churchill
Tribal Representative
Duckwater Shoshone Tribe

The Honorable Harold Frank
Chairman
Forest County Potawatomi Community of
Wisconsin

Ms. Grace Goad
Tribal Representative
Timbisha Shoshone Tribe

The Honorable Elizabeth Hansen
Chairwoman
Redwood Valley Rancheria of Pomo Indians of California

The Honorable Lori Harrison
Chairwoman of the Board of Directors
Las Vegas Indian Center

Mr. Bill Helmer
Tribal Historic Preservation Officer
Big Pine Pauite Tribe of the Owens Valley

The Honorable Mike Jackson, Sr.
President
Quechan Tribe of the Fort Yuma Indian Reservation, California & Arizona

Mr. John A. James
Chairman, Cabazon General Council
Cabazon Band of Mission Indians

Ms. Clara Belle Jim
Tribal Representative
Pahrump Paiute Tribe

The Honorable Roland E. Johnson
Governor
Pueblo of Laguna, New Mexico

The Honorable Jason Johnson
Governor
Pueblo of Acoma, New Mexico

Mr. Mel Joseph
Tribal Representative
Lone Pine Paiute-Shoshone Tribe

Mr. Gerald Kane
Tribal Representative
Bishop Paiute Indian Tribe

Mr. Darryl King
Tribal Representative
Chemehuevi Tribe

Ms. Jacqueline Johnson
Executive Director
National Congress of American Indians

The Honorable Joe Kennedy
Chairman
Timbisha Shoshone Tribe

Ms. Lawanda Laffoon
Tribal Representative
Colorado River Indian Tribes

Mr. Bill R. Larson
Shoshone Nation/Tribe

Mr. Bill Larson
Western Shoshone Defense Project

Mr. A. David Lester
Executive Director
Council of Energy Resource Tribes

The Honorable George R. Lewis
President
Ho-Chunk Nation of Wisconsin

Ms. Cynthia V. Lynch
Tribal Representative
Pahrump Paiute Tribe

The Honorable Maurice Lyons
Chairman
Morongo Band of Cahuilla Mission Indians of the Morongo Reservation, California

Ms. Dorena Martineau
Tribal Representative
Paiute Indian Tribes of Utah

The Honorable Nora McDowell
Chairwoman
Fort Mojave Indian Tribe of Arizona, California & Nevada

The Honorable Arlan D. Melendez
Tribal Chair
Reno-Sparks Indian Tribe

Mr. Calvin Meyers
Tribal Representative
Moapa Band of Paiutes

The Honorable Dean Mike
Chairman
Twenty-Nine Palms Band of Mission Indians of California

The Honorable Richard M. Milanovich
Chairman
Agua Caliente Band of Cahuilla Indians

Ms. Lalovi Miller
Tribal Representative
Moapa Band of Paiutes

The Honorable Antone Minthorn
Chairman, Board of Trustees
Confederated Tribes of the Umatilla Reservation, Oregon

Mr. Armand Minthorn
Confederated Tribes of the Umatilla Indian Reservation

The Honorable Alfreda L. Mitre
Chairwoman
Las Vegas Paiute Tribe

The Honorable Virgil Moose
Chairman
Big Pine Paiute Tribe of the Owens Valley

Ms. Gaylene Moose
Tribal Representative
Bishop Paiute Tribe

Mr. Wilfred Nabahe
Tribal Representative
Lone Pine Paiute-Shoshone Tribe

The Honorable Larry Nuckolls
Governor
Absentee Shawnee Tribe of Indians of Oklahoma

Mr. Willy Preacher
Tribal DOE Director
Shoshone-Bannock Tribe Fort Hall Business Council

The Honorable Kay Rhoads
Principal Chief
Sac & Fox Nation, Oklahoma

The Honorable William R. Rhodes
Governor
Gila River Indian Community of the Gila River Indian Reservation, Arizona

The Honorable Tony Salazar
Chairman
Kickapoo Tribe of Oklahoma

The Honorable Ruby Sam
Chairwoman
Duckwater Shoshone Tribe

The Honorable Joseph C. Saulque
Chairman
Benton Paiute Indian Tribe

Ms. Gevene E. Savala
Tribal Representative
Kaibab Band of Southern Paiutes

The Honorable George Scott
Town King
Thlopthlocco Tribal Town, Oklahoma

The Honorable Ona Segundo
Chairwoman
Kaibab Band of Southern Paiutes

The Honorable Arturo Senclair
Governor
Ysleta Del Sur Pueblo of Texas

The Honorable Joe Shirley, Jr.
President
Navajo Nation, Arizona, New Mexico & Utah

Mr. Herman Shorty
Navajo Nation

The Honorable Ivan L. Sidney
Chairman
Hopi Tribe of Arizona

The Honorable Barry E. Snyder, Sr.
President
Seneca Nation of New York

Mr. Philbert Swain
Moapa Band of Paiutes

Ms. Theresa A. Stone-Yanez
Tribal Historic Preservation Officer
Bishop Paiute Indian Tribe

The Honorable Ronald Suppah
Chairman
Confederated Tribes of the Warm Springs Reservation

Mr. Reginald Thorp
Emergency Management & Response Director
Shoshone-Bannock Tribe Fort Hall Business Council

Ms. Eleanor Tom
Tribal Representative
Paiute Indian Tribes of Utah

The Honorable Lora E. Tom
Chairwoman
Paiute Indian Tribe of Utah

Mr. Roger Tungovia
Emergency Management Services Coordinator
Hopi Tribal Council

Ms. Rebecca Van Lieshout
Coordinator, Tribal EPA
Forest County Potawatomi Community of Wisconsin

The Honorable Glenn Wasson
Chairperson
Lovelock Tribal Council

Mr. Ken Watteron
Timbisha Shoshone Tribe

The Honorable Lee Watterson
Chairman
Bishop Paiute Indian Tribe

Mr. Richard Wilder
Tribal Representative
Fort Independence

Genia Williams
Tribal Chairperson
Walker River Paiute Tribe

The Honorable Leona L. Williams
Chairwoman
Pinoleville Rancheria of Pomo Indians of California

The Honorable Charles Wood
Chairman
Chemehuevi Indian Tribe

The Honorable Marjianne Yonge
Chairwoman
Lone Pine Paiute-Shoshone Tribe

N.6 Environmental and Public Interest Groups

Mr. David Albright
President
Institute for Science and International Security

Ms. Joni Arends
Executive Director
Concerned Citizens for Nuclear Safety (CCNS)

Mr. John M. Bailey
Institute for Local Self-Reliance

Mr. Tom Bancroft
The Wilderness Society
Ecology & Economics Research Department

Mr. Tom Barry
The Center for International Policy

Mr. David Beckman
Natural Resources Defense Council
Los Angeles Office

Ms. Mavis Belisle
Director
Peace Farm

Ms. Jan Bennett
Public Affairs Representative
Entergy Nuclear Vermont Yankee

Mr. David Bradley
Executive Director
National Community Action Foundation

Mr. Jim C. Bridgman
Program Director
Alliance for Nuclear Accountability

Mr. Chuck Broscious
Executive Director
Environmental Defense Institute

Ms. Carol Brown
Office of Intergovernmental Affairs
City of Chicago

Ms. Carol Browner
Chairman of the Board
National Audubon Society

Dr. Robert D. Bullard
Director
Clark Atlanta University
Environmental Justice Resource Center

Ms. Kateri Callahan
President
Alliance to Save Energy

Mr. Will Callaway
Physicians for Social Responsibility

Ms. Laura Carlsen
Director, Americas Program
International Relations Center

Mrs. Nina Carter
Executive Director, Washington State Office
National Audubon Society

Mr. Thomas Cassidy
Director of Federal Programs
The Nature Conservancy

Ms. Christine Chandler
Responsible Environment Action League

Dr. Joseph Cirincione
Senior Associate & Director, Non-Proliferation Project
Carnegie Endowment for International Peace

Ms. Joan B. Claybrook
President
Public Citizen

Ms. Jodi Dart
Alliance for Nuclear Accountability

Mr. Larry Fahn
President, Board of Directors
Sierra Club

Ms. Janet Feldman
Sierra Club

Mr. John Flicker
Chief Executive Officer
National Audubon Society

Ms. Anna M. Frazier
Coordinator
Dine CARE

Mr. Bob Fulkerson
Progressive Leadership Alliance of Nevada

Ms. Beth Gallegos
Citizens Against Contamination

Ms. Beverly Gattis
President
STAND, Inc.

Mr. Eric Goldstein
Natural Resources Defense Council

Mr. Tom Goldtooth
Executive Director
Indigenous Environmental Network

Ms. Susan Gordon
Director
Alliance for Nuclear Accountability

Mr. Michael Govan
Dia Art Foundation

Ms. Lisa Gover
Program Director
National Tribal Environmental Council (NTEC)

Ms. Nicole Graysmith
Legal Aid of North Carolina
Environmental Poverty Law Project

Ms. Janet Greenwald
Citizens for Alternatives to Radioactive
Dumping (CARD)

Mr. Don Hancock
Director, Nuclear Waste Safety Program &
SRIC Administrator
Southwest Research & Information Center

Ms. Carolyn Hanson
Environmental Council of the States

Ms. Thea Harvey
Executive Director
Economists for Peace & Security at the Levy
Institute

Ms. Amelia Hellman
State Director
The Nature Conservancy
Nevada Field Office

Mr. Daniel Hirsch
President
Committee to Bridge the Gap

Mr. Robert Holden
Director
National Congress of American Indians (NCAI)
Emergency Management & Radioactive
Programs

Ms. Rachel Jacobson
Chief Operating Officer
National Fish & Wildlife Foundation

Mr. Toney Johnson
Citizens Against Nuclear Trash

Ms. Peggy Maze Johnson, Executive Director
Citizens Alert

Ms. Marylia Kelley
Tri-Valley CAREs

Mr. Seth Kirshenberg
Program Manager
Energy Communities Alliance

Mr. Fred Krupp
President
National Headquarters
Environmental Defense

Ms. Traci Laird
Regional Coordinator
Sierra Club
Southern Plains Regional Field Office

Reverend Mac Legerton
Center for Community Action

Mr. Ronald Lamb
Coalition for Health Concern

Ms. Kathryn Landreth
State Director
Nevada Field Office
The Nature Conservancy

Ms. Betsy Lawson
League of Women Voters

Mr. Lloyd Leonard
League of Women Voters

Mr. Pete Litster
Executive Director
Shundahai Network

Dave Lochbaum, Ph.D.
Sr. Nuclear Safety Engineer
Union of Concerned Scientists

Mr. Jim Lyon
Senior Director for Congressional & Federal
Affairs
National Wildlife Foundation

Mr. Arjun Makhijani, Ph.D.
Institute for Energy and Environmental Research

Mr. Kevin Martin
Executive Director
Peace Action Education Fund

Dr. Mildred McClain
Executive Director
Harambee House, Inc.
Projects: ACA-Net & Citizens for Environmental Justice

Mr. Steven J. McCormick
President & Chief Executive Officer
The Nature Conservancy

Mr. Taylor McKinnon
Desert Ecologist
Center for Biological Diversity

Ms. Elizabeth Merritt
Deputy General Counsel
National Trust for Historic Preservation

Mr. Allen Metscher
Citizens Advisory Council

Mr. Alfred Meyer
Alliance for Nuclear Accountability

Dr. LeRoy Moore
Consultant on Radiation Health Issues
Rocky Mountain Peace & Justice Center

Mr. Richard Moore
Executive Director
Southwest Network for Environmental & Economic Justice

Mr. Steve Moyer
Vice President for Governmental Affairs
Trout Unlimited

Robert K. Musil, Ph.D.
Executive Director and CEO
Physicians for Social Responsibility

Ms. Martez Norris
Administrator
Nuclear Waste Strategy Coalition

Mr. Albert (Brandt) Petrasek
State and Tribal Government Working Group

Mr. Ehrich Pica
Friends of the Earth

Mr. Gerald Pollet
Executive Director
Heart of America Northwest

Mr. Paul R. Portney
President & Senior Fellow
Resources for the Future

Ms. Meg Power
Senior Advisor
National Community Action Foundation

Ms. Laura Raicovich
Dia Art Foundation

Mr. Jim Riccio
Greenpeace International

Mr. Roger Rivera
President
National Hispanic Environmental Council

Nick Roth
Nuclear Age Peace Foundation

Mr. Thomas A. Schatz
President
Council for Citizens Against Government Waste

Mr. Paul Schwartz
National Campaign Director
Clean Water Action

Ms. Susan Shaer
Executive Director
Women’s Action for New Directions

Ms. Kassie Siegel
Air Climate and Energy Director
Center for Biological Diversity

Ms. Alice Slater
President
Global Resource Action Center for the Environment

Ms. Gail Small
Executive Director
Native Action

Mr. Derek Stack
Executive Director
Great Lakes United

Mr. John Tanner
Coalition 21

Jennifer Olaranna Viereck
Healing Ourselves & Mother Earth

Mr. Mark Wenzler
Sierra Club
Legislative Office

Mr. Louis Zeller
Blue Ridge Environmental Defense League

N.7 Other Groups and Individuals

Mr. & Mrs. Dirk and Marta Agee
Commissioner
Tempiute Grazing Association

Mr. Ralph Anderson
Project Manager, Plant Support
Nuclear Energy Institute

Mr. Robert A. Apel
Newcrest Resources, Inc.

Ms. Anna Aurilio
Director, Washington, DC Office
Environment America

Donald H. Baepler, Ph.D.
Executive Director
University of Nevada, Las Vegas
Harry Reid Center

Mr. Tom Barry
Senior Policy Analyst & Co-founder
International Relations Center

Mr. Gerald W. Baughman
Nevada Eagle Resources, LLC

Mr. Robert A. Beck
Executive Vice President
National Coal Council

Arden L. Bement, Ph.D.
Director
National Science Foundation

Mr. David Blee
Executive Director
U.S. Transport Council

Admiral, Retired Frank L. “Skip” Bowman
President & Chief Executive Officer
Nuclear Energy Institute

Mr. Jonathan M. Brown
Nevada Mining Association

Mr. Richard Bryan, Chairman
Nevada Commission on Nuclear Projects

Mr. Dennis P. Bryan
Converse Consultants

Jackie Cabasso
Executive Director
Western States Legal Foundation

Mr. Paul J. Burkett
Nevada Gold & Casinos, Inc.

Ms. Anne deLain Clark
Coordinator
Radioactive Waste Consultation Task Force
New Mexico Energy Minerals & Natural
Resources Dept.

Thomas B. Cochran, Ph.D.
Director, Nuclear Programs
Natural Resources Defense Council, Inc.
Washington Office

Ms. Kara Colton
National Governors’ Association (NGA)
Environment, Energy & Natural Resources
Division

Ms. Paula Cotter, Esq.
Senior Environmental Counsel
National Association of Attorneys General (NAAG)

Mr. Patrick Cummins
Air Quality Project Manager
Western Regional Air Partnership

Mr. Anthony DeSouza
Director, Board on Earth Studies & Natural Sciences
National Academy of Sciences

Mr. John M. Engler
President
National Association of Manufacturers

Mr. W. Scott Field
Policy Analyst
Western Interstate Energy Board (WIEB)

Mr. Jim Ford
Washington Representative
American Petroleum Institute

Mr. Robert E. Fronczak
Assistant Vice President, Environment & Hazardous Materials
Association of American Railroads (AAR)
Safety & Operations Dept.

Ms. Amy Greer
Natural Resources Defense Council
Public Education

Ms. Arlene Grider
President
Independence Chamber of Commerce

Mr. David Hawkins
Director, Climate Center
Natural Resources Defense Council
Washington Office

Ms. Angelina S. Howard
Executive Vice President
Nuclear Energy Institute

Mr. Walter Isaacson
President & CEO
The Aspen Institute
Program on Energy, the Environment & the Economy

Mr. Kevin Kamps
Nuclear Information & Resource Service

Ms. Jill Kennay
Assistant Director
Natural Land Institute

Mr. Steven Kerekes
Director, Media Relations
Nuclear Energy Institute

Ms. Sharon Kerrick
Manager
American Nuclear Society (ANS)
Outreach & Volunteer Dept.

Mr. Steven P. Kraft
Director, Spent Nuclear Fuel Management
Nuclear Energy Institute

Ms. Shauna Larsen
Government Relations Representative
American Public Power Assoc.

Mr. Douglas Larson
Executive Director
Western Interstate Energy Board (WIEB)

Mr. Edward W. Lent, III
Region III President
International Association of Emergency Managers
c/o General Physics Corporation

Mr. Paul Leventhal
Founding President
Nuclear Control Institute

Mr. Richard M. Loughery
Director, Environmental Activities
Edison Electric Institute

Mr. William Mackie
Program Manager
Western Governors' Association

Mr. Robert E. Marvin
Director
FRA/State Rail Safety Participation Program
c/o Transportation Division
Ohio Public Utilities Commission

Mr. Rod McCullum
Nuclear Energy Institute

Mr. David Mienke
Alliant Utilities, Inc.
Duane Arnold Energy Center

Mr. Brian J. O'Connell
Director, Nuclear Waste Program
National Assoc. of Regulatory Utility Commissioners (NARUC)

Ms. Mary Olson
Radioactive Waste Project & NIX MOX Campaign
Nuclear Information & Resource Service

Mr. Scott Palmer
Brotherhood of Locomotive Engineers & Trainment

Mr. Duane Parde
Executive Director
American Legislative Exchange Council (ALEC)

Mr. William Ramsey
Executive Director
Troutman Sanders

Mr. Randy Rawson
President
American Boiler Manufacturers Association

Mr. Jim B. Reed
Transportation Program Director
National Conference of State Legislators (NCSL)

Mr. Cort Richardson
Project Director
Council of State Governments - Eastern Regional Conference (CSG/ERC)

Mr. Robert Robinson
Senior Economist
Center for Applied Research

Dr. Budhi Sagar
Technical Director
Southwest Research Institute
Center for Nuclear Waste Regulatory Analyses

Ms. Lisa R. Sattler
Senior Policy Analyst
Council of State Governments-Midwest Office (CSG/MW)

Mr. Vincent Scoccia
Nye Regional Medical Center

Dr. David Shafer
Executive Director
CERM, Desert Research Institute
Center for Environmental Remediation & Monitoring

Ms. Diane Shea
Director, Natural Resources Committee
National Governors' Association

Ms. Linda Sikkema
Executive Director
National Conference of State Legislatures

Mr. Steven Specker
President and CEO
Electric Power Research Institute, Inc. (EPRI)

Dr. Klaus Stetzenbach
Director
University of Nevada, Las Vegas
Harry Reid Center for Environmental Studies

Mr. Bobby St. John
Media Coordinator
Washington TRU Solutions

Mr. Joe Strolin
Western Interstate Energy Board

Ms. Eileen Supko
Senior Consultant
Energy Resources International, Inc.

Mr. Robert Thompson
Energy Communities Alliance

Mr. Dave Trebisacci, CSP
Senior Fire Service Specialist
National Fire Protection Association (NFPA)

Mr. James S. Tulenko
President
American Nuclear Society

Mr. Chris Turner
Training Coordinator
International Association of Fire Fighters (IAFF)
Hazardous Materials Training Department

Mr. George D. Turner
President & Chief Executive Officer
American Nuclear Insurers

Ms. Barbara Bauman Tyran
Director, Washington Relations
Electric Power Research Institute

Ms. Julie Ufner
Associate Legislative Director
National Association of Counties (NACo)

Dr. Stephen Wells
President
Desert Research Institute

N.8 Reading Rooms and Libraries

U.S. Department of Energy Headquarters Office
Public Reading Room
Washington, D.C.

Pahrump Yucca Mountain Information Center
Pahrump, NV

Esmeralda County Yucca Mountain Oversight Office
Goldfield, NV

Nye County Department of Natural Resources and Federal Facilities
Pahrump, NV

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
Administrator
Savannah River Operations

University of South Carolina-Aiken, Gregg-Graniteville Library
Public Reading Room

Ms. Kathy Edwards
Nevada State Library & Archives

Ms. Sandra Groleau
Bates College Library

Ms. Amy Sue Goodin
Associate Director of Research
University of New Mexico
Institute for Public Policy

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
Dimond Library

Librarian
San Jose State University
Martin Luther King, Jr. Library
Government Publications Department

Librarian
University of Colorado, Boulder
Library - Government Publications

Librarian
University Library, California State University
Government Documents

Librarian
Susanville District Library

Librarian
Sparks Branch Library

Librarian
Fishlake Branch Library

Librarian
Carson City Library
Reference Department

Librarian
Laughlin Branch Library

Librarian
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
Public Reading Room

Mr. Tim D. Petrosky
Public Affairs Director
Consumer Energy
Big Rock Point

Mr. William H. Schalk
Communications Manager
American Electric Power Company
Cook Visitor Information Center

Ms. Susie Skarl
Head, Government Publications
University of Nevada, Las Vegas
Lied Library

Ms. Barbara Sullivan
Center for Health, Environment and Justice
CHEJ Library

Ms. T. Twyford
Librarian
Tecopa Library

Mr. John Walters
Utah State University
Merrill Library

Lincoln County Nuclear Waste Project Office
Caliente, NV

The University of Nevada Libraries
Business and Government Information Center
Reno, NV

Mr. Dan Barkley
University of New Mexico
Zimmerman Library

Mr. Hui Hua Chua
Michigan State University

Ms. Kay Collins
University of California, Irvine
Langson Library

Ms. Sherry DeDecker
University of California, Santa Barbara
Davidson Library - Government Information Center

Ms. Heather Elliott
Clearinghouse Coordinator, Nevada State Clearinghouse
Department of Administration
State of Nevada
Public Reading Room

Ms. Verna Graybill
Librarian
Northwestern Oklahoma State University
J.W. Martin Library Depository

Mr. Michele Hayslett
North Carolina State University Libraries
Government Information Services – RISD

Mr. Mark Holt
Library of Congress

Ms. Alisa Huckle
Mr. Brent Jacobson
Idaho Operations Office
INEEL Technical Library
U.S. DOE Public Reading Room

Mr. Walter Jones
University of Utah
Marriott Library, Special Collections

Librarian
University of Notre Dame
Hesburgh Library - Government Documents Center

Librarian
University of California, Riverside
Rivera Library - Government Publications Department

Librarian
U.S. Geological Survey
Serial Records Unit
National Center

Librarian
Spring Valley Library

Librarian
Billinghurst Middle School Library

Librarian
Inyo County Free Library

Librarian
New Mexico State University
Branson Library – Documents

Librarian
North Las Vegas Public Library

Librarian
Brainerd Memorial Library

Librarian
University of Rhode Island
Library - Government Publications Office

Librarian
University of Maryland, Baltimore County
Albin O. Kuhn Library and Gallery - Government Documents

Mr. Gary Morell
College Hill Library
Rocky Flats Field Office

Mr. Walter Perry
U.S. Department of Energy Information Center
Oak Ridge Operations Office

Ms. Angela Riley
Community Relations Representative
TXU Electric & Gas
Comanche Peak Visitors Center

Mr. John Shuler
Richard J. Daley Library
Documents, Maps and Microforms Department
University of Illinois at Chicago

Mr. Tim Sutherland
Indiana University
Northwest Library, Documents Department

Mr. Carl E. Unger
Senior Communications Representative
Public Information Center
Arizona Public Service Company
Palo Verde Nuclear Generating Station

Ms. Elaine Watson
Boise State University
Library - Government Documents

Ms. Beryl A. Zundel
Sunrise Library

Mr. Bill Zimmerman
U.S. Department of Energy
Bonneville Power Administration
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