APPENDIX H
TRANSPORTATION

This appendix provides an overview of the approach used to assess the potential human health risks from transportation activities. Topics include the scope of the assessment; packaging and transportation regulations; determination of potential transportation routes; analytical methods used for the risk assessment (e.g., computer models); and important assessment assumptions. The results of this assessment are expressed in terms of doses and risks to transportation workers and the exposed population from both incident-free operations and accident conditions. In addition, to aid in understanding and interpreting the results, specific areas of uncertainty are described with an emphasis on how these uncertainties may affect comparisons among alternatives.

H.1 INTRODUCTION

Transportation of any commodity involves a risk to both transportation crewmembers and members of the public. This risk results directly from transportation-related accidents and indirectly from increased levels of pollution from vehicle emissions, regardless of the cargo. Transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the materials themselves. To permit a complete appraisal of the environmental impacts of the proposed actions and alternatives analyzed in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*, the human health risks associated with the transportation of radioactive materials on public highways and railroads were assessed. The anticipated impacts of each alternative are presented, including projected doses and health effects.

Risk assessment results are presented in this appendix in terms of "per-shipment" risk factors, as well as the total risks under a given alternative. Per-shipment risk factors are used to estimate the risk from a single shipment. The total risks under a given alternative are estimated by multiplying the expected number of shipments by the appropriate per-shipment risk factors.

H.2 ASSESSMENT SCOPE

This section describes the scope of the transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, transportation modes, and receptors considered. Several shipping arrangements for various radioactive wastes, involving both onsite and offsite public highways and rail systems, are being considered to cover all of the alternatives evaluated. Additional assessment details are provided in the remaining sections of this appendix.

H.2.1 Transportation-Related Activities

The transportation risk assessment is limited to estimating the human health risks related to transportation under each alternative. The risks to workers and the public during loading, unloading, and handling prior to a shipment under each alternative are provided in the "Public and Occupational Health and Safety—Facility Accidents" and "Public and Occupational Health and Safety—Normal Operations" sections in Chapter 4 of this environmental impact statement (EIS). The impacts of increased transportation levels on local traffic flow or infrastructure under each alternative are addressed in the "Local Transportation" subsections in the "Socioeconomics" sections of Chapter 4.

H.2.2 Radiological Impacts

The risk to the affected population is a measure of the radiological risk posed to society as a whole by the alternative being considered. As such, the impact on the affected population is used as the primary means of comparing various alternatives. For each alternative, radiological risks (risks that result from the radioactive nature of the materials) of transportation were assessed for both incident-free (normal) and accident conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of members of the public.

All radiological impacts are calculated in terms of the committed dose received by the exposed populations and its associated health effects. The calculated radiation dose is the total effective dose equivalent (10 CFR 20), the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of roentgen equivalent man (rem) for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of latent cancer fatalities (LCFs) in exposed populations using the dose-to-risk conversion factors recommended by the U.S. Department of Energy's (DOE's) Office of National Environmental Policy Act Policy and Compliance, which are based on Interagency Steering Committee on Radiation Safety guidance (DOE 2003).

H.2.3 Nonradiological Impacts

In addition to the radiological risks posed by transportation activities, nonradiological, vehicle-related risks (risks unrelated to radioactive cargo) are assessed for the same transportation routes. Nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for both incident-free and accident conditions. The nonradiological accident risk refers to the potential occurrence of transportation accidents resulting in fatalities unrelated to the shipment of cargo. Nonradiological risks are presented in terms of estimated fatalities.

Nonradiological risks during incident-free transportation conditions could be caused by potential exposure to increased vehicle exhaust emissions. As explained in Section H.5.2, these emission impacts were not considered.

H.2.4 Transportation Modes

All shipments were assumed to use either dedicated truck or rail transportation modes.

H.2.5 Receptors

Transportation-related risks were calculated and presented separately for workers and members of the general public. The workers considered were truck and rail crewmembers involved in transportation and inspection of the packages. The general public included all persons who could be exposed to a shipment while it is either moving or stopped during transit. Potential risks were estimated for the affected populations and for a hypothetical maximally exposed individual (MEI). For incident-free operation, the affected population included individuals living within 800 meters (0.5 miles) of each side of the road or rail, and the MEI was a resident living near the highway or railroad, who would be exposed to all shipments transported by road or rail. For accident conditions, the affected population included individuals residing within 80 kilometers (50 miles) of the accident, and the MEI was an individual located 100 meters (330 feet) directly downwind from the accident.

H.3 PACKAGING AND TRANSPORTATION REGULATIONS

H.3.1 Packaging Regulations

The primary regulatory approach to promoting safety from radiological exposure is specification of standards for the packaging of radioactive materials. Packaging represents the primary barrier between the radioactive material being transported and the public, workers, and environment. Transportation packaging for radioactive materials must be designed, constructed, and maintained to contain and shield its contents during normal transport conditions. For highly radioactive material, such as high-level radioactive waste (HLW) or spent nuclear fuel (SNF), packaging must contain and shield its contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material to be packaged. Four basic types of packaging are used: Excepted, Industrial, Type A, and Type B.

Excepted packages are limited to transporting materials with extremely low levels of radioactivity. Industrial packages are used to transport materials that, because of their low concentration of radioactive materials, present a limited hazard to the public and the environment. Type A containers and packages are designed to protect and retain their contents under normal transportation conditions and to provide sufficient shielding to limit radiation exposure to handling personnel. Type B containers and packages are used to transport material with the highest radioactivity levels and are designed to protect and retain their contents under transportation accident conditions (for more detail, see the following sections).

Radioactive materials shipped in Type A containers or packages are subject to specific radioactivity limits, identified as A1 and A2 values in Title 49 of the *Code of Federal Regulations (CFR)*, Section 173.435 (49 CFR 173.435). In addition, external radiation limits, as prescribed in Title 49 of the CFR, Section 173.441 (49 CFR 173.441), must be met. If the A1 or A2 limits are exceeded and material does not meet the low-specific-activity definition and requirements, the material must be shipped in a Type B container. If the material qualifies as having a low specific activity (number of decays per second per amount of substance), as defined in Title 10 of the *CFR*, Part 71 (10 CFR 71) and Title 49 of the CFR, Part 173 (49 CFR 173), it may be shipped in an approved low-specific-activity shipping container that meets the requirements of Title 49 of the CFR, Section 173.427(b)(4), such as Industrial or Type A packaging. Type B containers or casks are subject to the radiation limits in 49 CFR 173.441, but no quantity limits are imposed except in the case of fissile materials and plutonium.

Type A packages are designed to retain their radioactive contents in normal transport. Under normal conditions, a Type A package must withstand the following conditions:

- Operating temperatures ranging from –40 degrees Celsius (°C) to 70 °C (–40 degrees Fahrenheit [°F] to 158 °F)
- A reduction of ambient pressure to 25 kilopascals (3.6 pounds per square inch), such that the containment system will retain its radioactive contents
- Normal vibration experienced during transportation
- Simulated rainfall of 5 centimeters (2 inches) per hour for 1 hour
- Free fall from 0.3 to 1.2 meters (1 to 4 feet), depending on the package weight
- Water immersion-compression tests

- Impact of a 6-kilogram (13.2-pound) steel cylinder with rounded ends dropped from 1 meter (40 inches) onto the most vulnerable surface

- Five times the mass of the gross weight of the package for 24 hours

Type B packages are designed to retain their radioactive contents under both normal and accident conditions. In addition to the testing for normal transportation conditions outlined above, a Type B package must withstand:

- Free drop from 9.1 meters (30 feet) onto an unyielding surface in a way most likely to cause damage

- Free drop from 1 meter (3.3 feet) onto the end of a 15-centimeter-diameter (6-inch-diameter) vertical steel bar

- Exposure to temperatures of 800 °C (1,475 °F) for at least 30 minutes

- Immersion in at least 15 meters (50 feet) of water for 8 hours

- For some packages, immersion in at least 0.9 meters (3 feet) of water for 8 hours in an orientation most likely to result in leakage

Compliance with these requirements is demonstrated by using a combination of simple calculating methods, computer modeling techniques, and scale-model or full-scale testing of packages.

H.3.2 Transportation Regulations

The regulatory standards for packaging and transporting radioactive materials are designed to achieve four primary objectives:

- Protect persons and property from radiation emitted from packages during transportation by specific limitations on the allowable radiation levels.

- Contain radioactive material in the package (achieved by packaging design requirements based on performance-oriented packaging integrity tests and environmental criteria).

- Prevent nuclear criticality (an unplanned nuclear chain reaction that may occur as a result of concentrating too much fissile material in one place).

- Provide physical protection against theft and sabotage during transit.

The U.S. Department of Transportation (DOT) regulates the transportation of hazardous materials for interstate commerce by land, air, and water. DOT specifically regulates the carriers of radioactive materials and the conditions of transport, such as routing, handling and storage, and commercial motor vehicle and driver requirements. DOT also regulates the shipping papers, labeling, classification, and marking of radioactive material packages. Transportation of hazardous materials within the Washington State is regulated according to *Washington Administrative Code* Sections 173-303-240 through 173-303-270 and Chapters 246-231 and 446-50.

The U.S. Nuclear Regulatory Commission (NRC) regulates the packaging and transportation of radioactive material for its licensees, including commercial shippers of radioactive materials. In addition, under an agreement with DOT, NRC sets the standards for packages containing fissile materials and Type B packages.

DOE, through its management directives, orders, and contractual agreements, ensures the protection of public health and safety by imposing standards equivalent to those of DOT and NRC on its transportation activities. In accordance with Title 49 of the CFR, Section 173.7(d) (49 CFR 173.7[d]), packages made by or under the direction of DOE may be used to transport Class 7 materials (radioactive materials) when the packages have been evaluated, approved, and certified by DOE against packaging standards equivalent to those specified in 10 CFR 71.

DOT also has requirements that help reduce transportation impacts. Some requirements affect drivers, packaging, labeling, marking, and placarding. Others specify the maximum dose rate from radioactive material shipments to help reduce incident-free transportation doses.

The U.S. Department of Homeland Security (DHS) is responsible for establishing policies for, and coordinating civil emergency management, planning, and interaction with, Federal Executive agencies that have emergency response functions in the event of a transportation incident. Guidelines for response actions have been outlined in the *National Response Framework* (*NRF*) (FEMA 2008a) in the event a transportation incident involving nuclear material occurs.

DHS would use the Federal Emergency Management Agency, an organization within DHS, to coordinate Federal and state participation in developing emergency response plans and to be responsible for the development and maintenance of the *Nuclear/Radiological Incident Annex* (*NRIA*) (FEMA 2008b) to the *NRF*. *NRIA*/*NRF* describes the policies, situations, concepts of operations, and responsibilities of the Federal departments and agencies governing the immediate response and short-term recovery activities for incidents involving release of radioactive materials to address the consequences of the event.

The Interstate Commerce Commission is responsible for regulation of the economic aspects of overland shipments of radioactive materials. The Commission issues operating authorities to carriers and monitors and approves freight rates.

H.4 TRANSPORTATION ANALYSIS IMPACT METHODOLOGY

The transportation risk assessment was based on the alternatives described in Chapter 2 of this *TC & WM EIS*. Figure H–1 summarizes the transportation risk assessment methodology. After the EIS alternatives were identified and the requirements of the shipping campaign were understood, data were collected on the material characteristics and accident parameters.

The transportation impacts calculated and analyzed in this *TC & WM EIS* are presented in two parts: impacts of incident-free or routine transportation and impacts of transportation accidents. The impacts of incident-free transportation and transportation accidents are further divided into nonradiological and radiological impacts. Nonradiological impacts of incident-free transportation and transportation accidents could result from vehicular emissions and traffic fatalities, respectively. Radiological impacts of incident-free transportation include impacts on members of the public and the workers (crew) from radiation emanating from materials within the package. Only under severe accident conditions, which have a low probability of occurrence, could a transportation package of the type used to transport radioactive material be damaged to the point that radioactivity could be released to the environment.

The impacts of transportation accidents are expressed in terms of probabilistic risk, which is the probability of an accident multiplied by the consequences of that accident and summed over all reasonable accident conditions. Hypothetical transportation accident conditions ranging from low-speed "fender bender" collisions to high-speed collisions with or without fires were analyzed. The frequencies

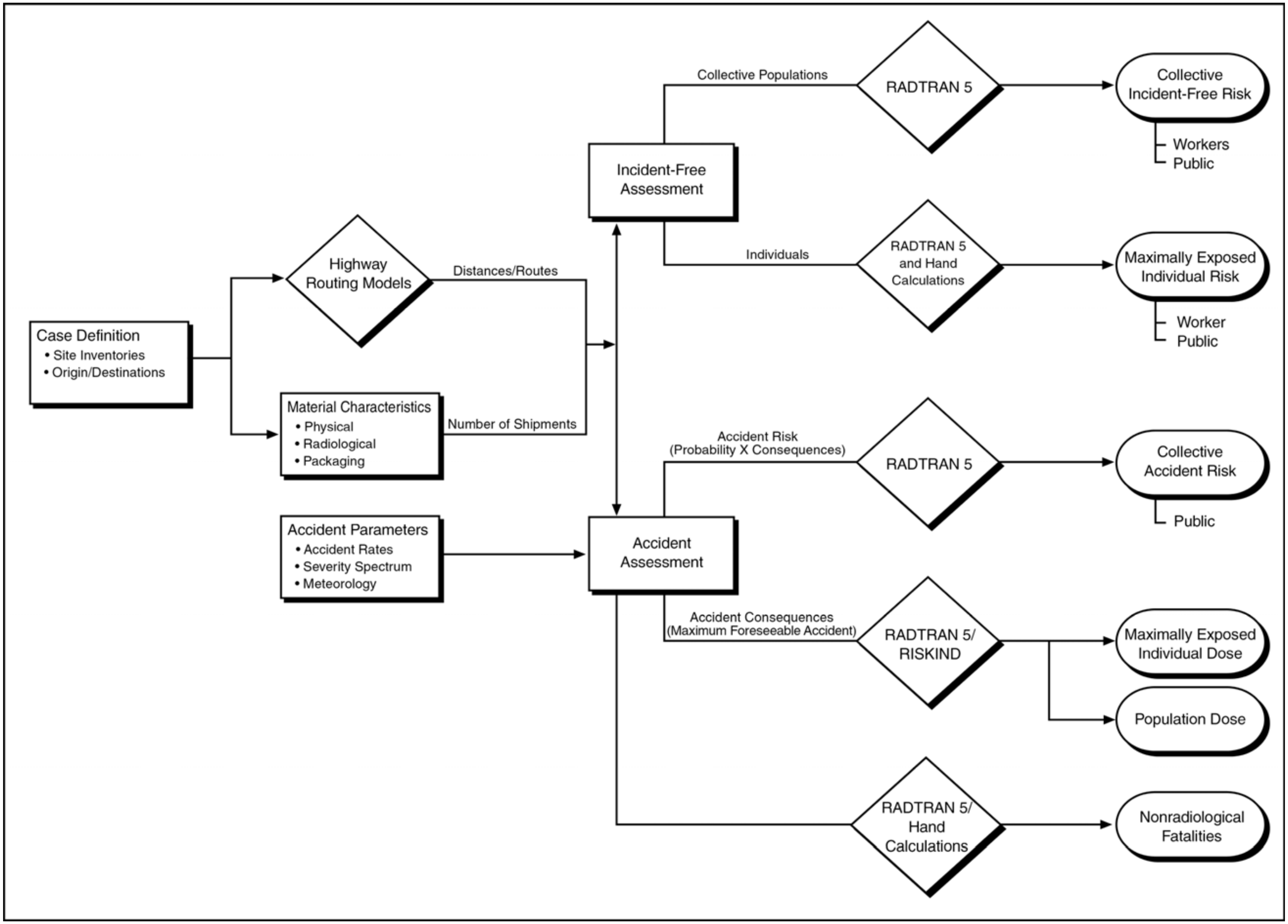

Figure H–1. Transportation Risk Assessment

of accidents and consequences were evaluated using a method developed by NRC and originally published in NUREG-0170, *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes (Radioactive Material Transport Study)* (NRC 1977); NUREG/CR-4829, *Shipping Container Response to Severe Highway and Railway Accident Conditions (Modal Study)* (Fischer et al. 1987); and NUREG/CR-6672, *Reexamination of Spent Fuel Shipment Risk Estimates (Reexamination Study)* (Sprung et al. 2000). Radiological accident risk is expressed as additional LCFs. Nonradiological accident risk is expressed as additional traffic fatalities. Incident-free radiological risk is expressed as additional LCFs.

Transportation-related risks were calculated and are presented separately for workers and members of the general public. The workers considered were truck/rail crewmembers involved in the act of transporting radioactive materials. The general public included all persons who could be exposed to a shipment while it is moving or stopped during transit.

The first step in the ground transportation analysis is to determine the distances and populations along the routes. The TRAGIS [Transportation Routing Analysis Geographic Information System] computer program (Johnson and Michelhaugh 2003) was used to choose representative routes and associated distances and populations. This information, along with the properties of the material being shipped and route-specific accident frequencies, was entered into the RADTRAN 5 [Radioactive Material Transportation] computer code (Neuhauser and Kanipe 2003), which calculated incident and accident risks on a per-shipment basis. The risks under each alternative were determined by summing the products of per-shipment risks for each waste by the number of shipments.

The RADTRAN 5 computer code (Neuhauser and Kanipe 2003) was used for both incident-free and accident risk assessments to estimate the impacts on populations. RADTRAN 5 was developed by Sandia National Laboratories to calculate population risks associated with transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. RADTRAN 5 was used to calculate the doses to MEIs during incident-free operations.

The RADTRAN 5 population risk calculations include both the consequences and probabilities of potential exposure events. The RADTRAN 5 code consequence analyses include cloud shine, ground shine, inhalation, and resuspension exposures. The collective population risk is a measure of the total radiological risk posed to society as a whole by the alternative being considered. As such, the collective population risk was used as the primary means of comparing the various alternatives.

The RISKIND [Risks and Consequences of Radiological Material Transport] computer code (Yuan et al. 1995) was used to estimate the doses to MEIs and populations from the maximum reasonably foreseeable transportation accident. The RISKIND computer code was developed for DOE's Office of Civilian Radioactive Waste Management to analyze the exposure of individuals during incident-free transportation. In addition, the RISKIND code was designed to allow detailed assessment of the consequences to individuals and population subgroups from severe transportation accidents under various environmental settings.

The RISKIND calculations were conducted to supplement the collective risk results calculated with RADTRAN 5. Whereas the collective risk results provide a measure of the overall risks under each alternative, the RISKIND calculations are meant to address areas of specific concern to individuals and population subgroups. Essentially, the RISKIND analyses are meant to address "what if" questions, such as "What if I live next to a site access road?" or "What if an accident happens near my town?"

H.4.1 Transportation Routes

To assess incident-free and transportation accident impacts, route characteristics were determined for offsite shipments from the Hanford Site (Hanford) in Richland, Washington, and for offsite shipments from other DOE facilities to Hanford, as well as for onsite shipments between the various waste processing plants and burial locations in the 200-East and 200-West Areas. For offsite transports, highway and rail routes were determined using the TRAGIS computer program (Johnson and Michelhaugh 2003). For almost all transports, direct rail routes between origin and destination were generated by TRAGIS; therefore, limited intermodal transports were needed. Rail transports to the Nevada Test Site (NTS) and the INL Materials and Fuels Complex would require intermodal transfers. Since there were only two rail shipments requiring intermodal transfers followed by short (less than 50-kilometer [31-mile]) truck transports, no specific intermodal activities were evaluated.

The TRAGIS computer program is a geographic information system-based transportation analysis computer program used to identify and select highway, rail, and waterway routes for transporting radioactive materials within the United States. Both the road and rail network are 1:100,000-scale databases that were developed from the U.S. Geological Survey digital line graphs and the U.S. Census Bureau Topological Integrated Geographic Encoding and Referencing System. The population densities along each route were derived from 2000 census data. The features in TRAGIS allow users to determine routes for shipment of radioactive materials that conform to DOT regulations, as specified in Title 49 of the CFR, Part 397 (49 CFR 397).

H.4.1.1 Offsite Route Characteristics

Route characteristics important to radiological risk assessment include the total shipment distance and the population distribution along the route. The specific route selected determines both the total potentially exposed population and the expected frequency of transportation-related accidents. The population densities along each route were derived from 2000 census data (Johnson and Michelhaugh 2003). Rural, suburban, and urban areas were characterized according to the following breakdown.

- Rural population densities range from 0 to 54 persons per square kilometer (0 to 139 persons per square mile).
- Suburban population densities range from 55 to 1,284 persons per square kilometer (140 to 3,326 persons per square mile).
- Urban population densities include all population densities greater than 1,284 persons per square kilometer (3,326 persons per square mile).

The affected population (for route characterization and incident-free dose calculation) includes all persons living within 800 meters (0.5 miles) of each side of the road.

H.4.1.1.1 Tank Closure Alternatives

Except for transuranic (TRU) waste, all radioactive waste generated during tank closure would be disposed of (i.e., ILAW) or stored (i.e., IHLW) on site. The TRU waste would be transported to the Waste Isolation Pilot Project (WIPP). Route characteristics for WIPP transports are summarized in Table H–1.

Table H–1. Tank Closure Alternatives – Offsite Transport Truck and Rail Route Characteristics

From	To	Nominal Distance (kilometers)	Distance Traveled in Zone (kilometers)			Population Density in Zone (number per square kilometer)			Number of Affected Persons
			Rural	Suburban	Urban	Rural	Suburban	Urban	
Truck Routes									
Hanford	WIPP	3,080	2,615	398	67	7.3	338.7	2,305.2	492,812
Rail Routes									
Hanford	WIPP	3,531	3,117	345	69	5.5	409.9	2,252.3	501,625

Note: To convert kilometers to miles, multiply by 0.6214; number per square kilometer to number per square mile, by 2.59.
Key: Hanford=Hanford Site; WIPP=Waste Isolation Pilot Plant.

The truck and rail routes that were analyzed for shipments of radioactive waste materials to WIPP are shown in Figure H–2. The truck transportation routes that were analyzed were similar to those evaluated in the *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement (WIPP SEIS-II)* (DOE 1997). The rail route that was analyzed for transport of TRU waste to WIPP is consistent with the assumptions made in the *WIPP SEIS-II.*

H.4.1.1.2 FFTF Decommissioning Alternatives

The main offsite transports used for Fast Flux Test Facility (FFTF) decommissioning could include transportation of remote-handled special components (RH-SCs) and radioactively contaminated bulk sodium to Idaho National Laboratory (INL) for treatment and recovery of sodium. The treated sodium residuals from the RH-SCs and treated bulk sodium would be sent back to Hanford for reuse by the Office of River Protection for the Waste Treatment Plant (WTP) or Hanford tanks corrosion control. The treated RH-SCs could be shipped back to Hanford or sent to the NTS for disposal. Route characteristics for INL and NTS are summarized in Table H–2.

Table H–2. FFTF Decommissioning Alternatives – Offsite Transport Truck and Rail Route Characteristics

From	To	Nominal Distance (kilometers)	Distance Traveled in Zone (kilometers)			Population Density in Zone (number per square kilometer)			Number of Affected Persons
			Rural	Suburban	Urban	Rural	Suburban	Urban	
Truck Routes									
FFTF	INL	968	813	140	15	9.5	300.9	2,184.1	132,665
INL	NTS	1,180	935	197	48	8.8	361.3	2,457.8	315,742
Rail Routes									
FFTF	INL	1,062	936	106	20	6.9	400.9	2,235.0	150,304
INL	NTS	1,460	1,282	143	35	4.4	395.2	2,410.8	233,489

Note: To convert kilometers to miles, multiply by 0.6214; number per square kilometer to number per square mile, by 2.59.
Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; NTS=Nevada Test Site.

The truck and rail routes that were analyzed for shipments of radioactive waste materials are shown in Figure H–3. Rail transports for disposal at NTS would require intermodal transfers. Because only two shipments were assumed to be disposed of at NTS, no specific intermodal analysis was performed.

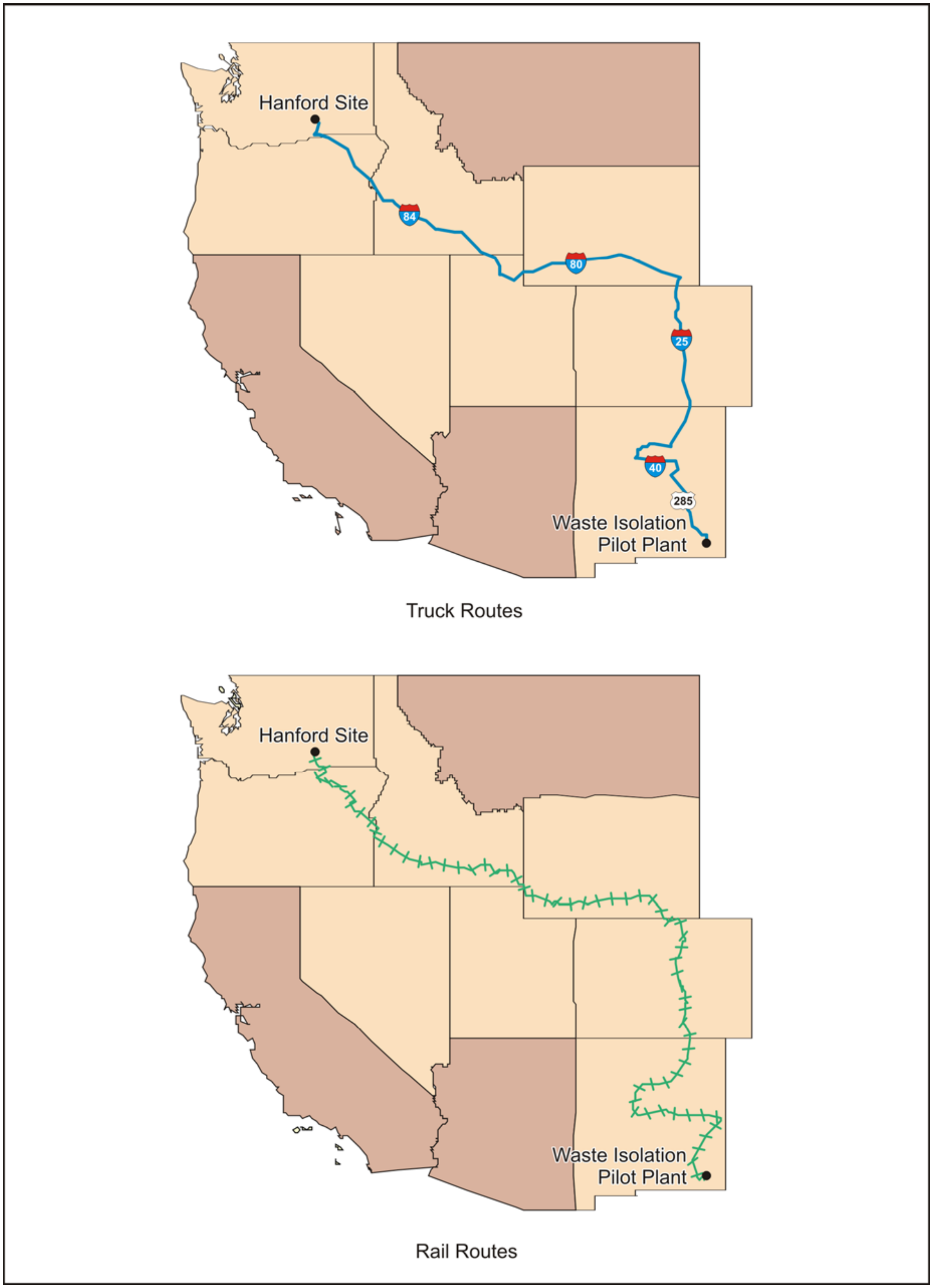

Figure H–2. Tank Closure Alternatives – Analyzed Truck and Rail Routes

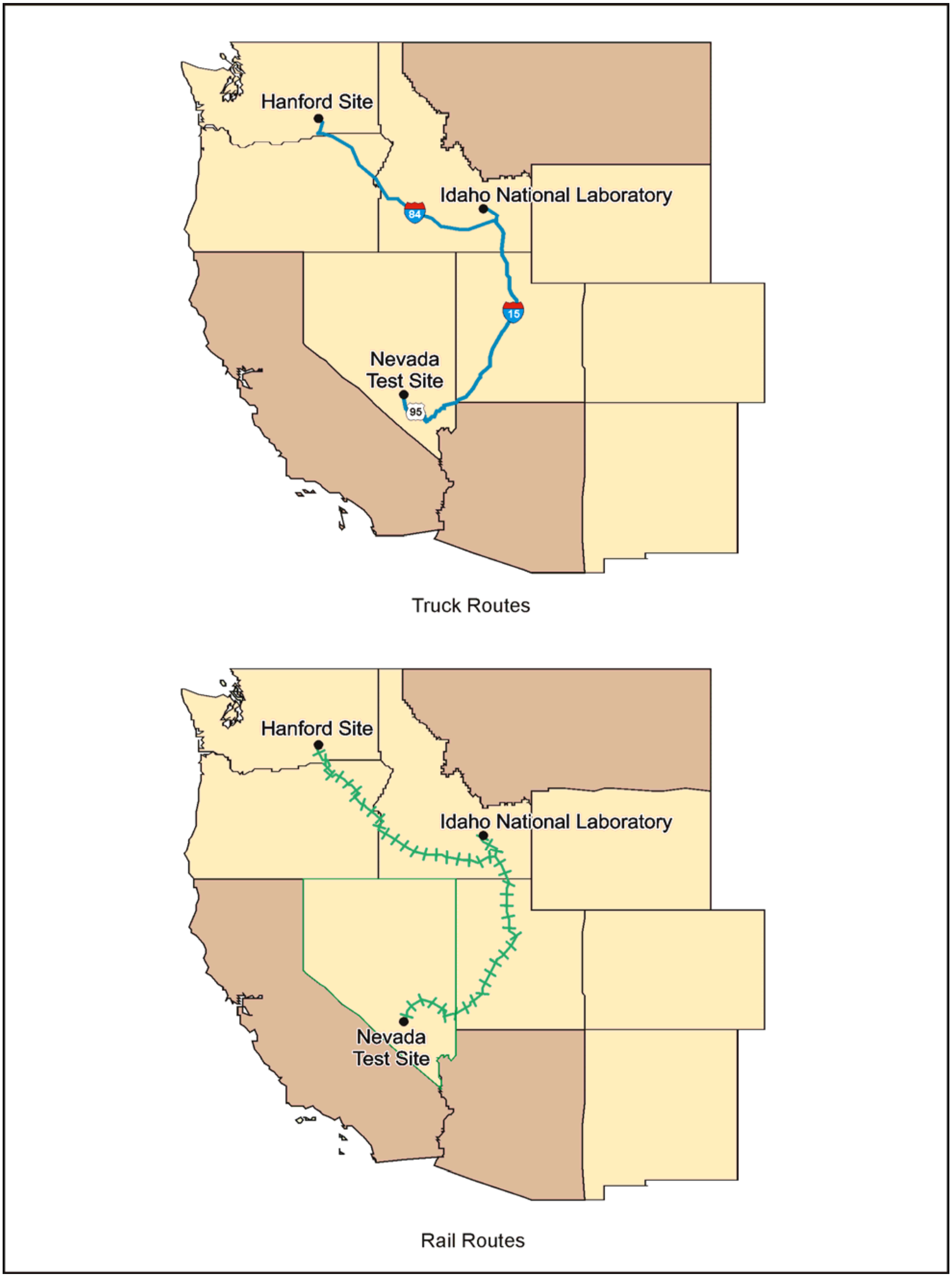

Figure H–3. FFTF Decommissioning Alternatives – Analyzed Truck and Rail Routes

H.4.1.1.3 Waste Management Alternatives

Hanford is one of two regional disposal facilities for DOE's low-level radioactive waste (LLW) and mixed low-level radioactive waste (MLLW), based on the February 2000 Record of Decision regarding the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (65 FR 10061). Accordingly, Hanford is expected to receive both LLW and MLLW from other DOE sites. Route characteristics for offsite radioactive transports from DOE sites to Hanford are summarized in Table H–3**.**

Table H–3. Waste Management Alternatives – Offsite Transport Truck and Rail Route Characteristics

From	To	Nominal Distance (kilometers)	Distance Traveled in Zone (kilometers)			Population Density in Zone (number per square kilometer)			Number of Affected Persons
			Rural	Suburban	Urban	Rural	Suburban	Urban	
Truck Routes									
ANL-E	Hanford	3,238	2,766	434	38	9.7	292.9	2,220.2	381,879
BNL		4,747	3,576	1,032	139	11.6	319.3	2,485.4	1,147,541
INL/NR		1,023	857	149	17	9.5	306.4	2,174.4	144,960
LANL		2,558	2,138	363	57	8.0	334.1	2,320.4	433,663
ORNL		4,023	3,227	721	75	10.2	306.7	2,215.8	671,349
Paducah		3,541	2,917	558	66	9.2	318.3	2,200.2	557,889
Portsmouth		4,064	3,281	722	61	11.3	292.4	2,214.8	614,096
SRS		4,443	3,410	919	114	10.4	327.7	2,248.5	947,736
West Valley		4,225	3,293	856	76	11.3	292.5	2,261.0	733,044
Rail Routes									
ANL-E	Hanford	3,276	2,751	425	100	5.7	361.3	2,540.6	677,558
BNL		4,876	3,693	908	275	8.1	389.8	2,694.6	1,798,614
INL/NR		1,062	936	106	20	6.9	400.0	2,235.0	150,305
LANL[a]		NA	NA	NA	NA	NA	NA	NA	NA
ORNL		4,271	3,420	703	148	7.8	365.1	2,357.8	1,009,844
Paducah		3,723	3,206	450	67	6.1	356.9	2,203.4	525,575
Portsmouth		3,891	3,204	559	128	7.0	373.7	2,355.7	850,824
SRS		4,766	3,699	878	189	7.8	396.3	2,299.9	1,299,605
West Valley		4,169	3,322	680	167	7.3	388.9	2,420.0	1,106,548

[a] No direct rail connection to Los Alamos National Laboratory.

Note: To convert kilometers to miles, multiply by 0.6214; number per square kilometer to number per square mile, by 2.59.

Key: ANL-E=Argonne National Laboratory-East; BNL=Brookhaven National Laboratory; Hanford=Hanford Site; INL/NR=Idaho National Laboratory/Naval Reactor Facility; LANL=Los Alamos National Laboratory; NA=not analyzed; ORNL=Oak Ridge National Laboratory; SRS=Savannah River Site; West Valley=West Valley Demonstration Project.

Truck and rail routes that were analyzed for shipments of radioactive waste materials are shown in Figure H–4.

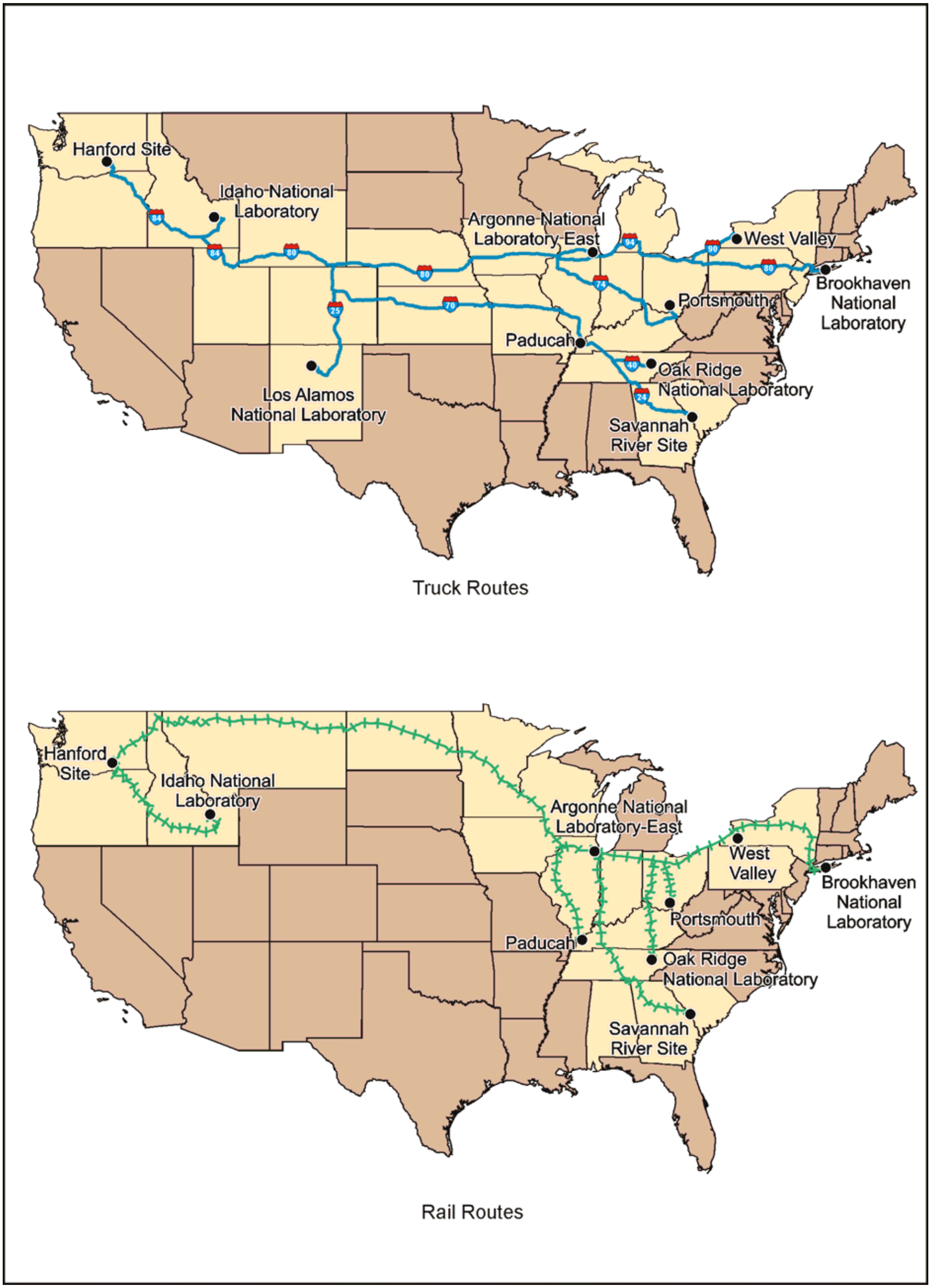

Figure H–4. Waste Management Alternatives – Analyzed Truck and Rail Routes

H.4.1.2 Onsite Route Characteristics

Onsite transport of waste materials would occur within either the 200-East or 200-West Area (under the Tank Closure alternatives), between FFTF and the 200 Areas (under the FFTF Decommissioning alternatives), and between the various facilities and the disposal locations within the 200 Areas (under the Waste Management alternatives). For transports within the 200-East and 200-West Areas (under the Tank Closure and Waste Management alternatives), waste was conservatively assumed to be generated at one site and transported to another. The distance traveled between the sites would be about 16 kilometers (10 miles), half of which would occur within the two areas. The population density on the road between the sites is 1 person per 2 square kilometers (about 4 persons per 3 square miles) (Johnson and Michelhaugh 2003). The population density while the transport is within any one of the areas was assumed to be the same as the population density of the 200-East Area, or 185 persons per square kilometer (479 persons per square mile).[1] This assumption is conservative, as both the road and the site are closed to the public and the individuals working within these areas are considered facility workers who would likely be exposed to more radiation than that emanating from waste packages during transport. For accident conditions, the population density up to an 80-kilometer (50-mile) radius was based on the average population densities for the 200-East and 200-West Areas. The total population within 80 kilometers (50 miles) of these two sites ranges from about 451,600 to 489,000. The 80-kilometer (50-mile) average population density would be about 24 persons per square kilometer (62 persons per square mile). This assumption would result in a conservative population dose because no member of the public resides within the first 10 kilometers (6 miles) of the road.

For transports under the FFTF Decommissioning alternatives, the onsite distance traveled between FFTF and various facilities in the 200 Areas ranges from 24 to 37 kilometers (15 to 23 miles).[2] The population density on the road between the sites is 1 per 10 square kilometers (Johnson and Michelhaugh 2003). The population density while the transport is within the 200 Areas was assumed to be the same as the population density of the 200-East Area (185 persons per square kilometer [479 persons per square mile]).

H.4.2 Radioactive Material Shipments

All waste types were assumed to be in certified or certified-equivalent packagings and containers and to be transported using exclusive-use vehicles. Legal-weight heavy-haul combination trucks would be used for highway transportation. Type A packages would be transported on common flatbed or covered trailers; Type B packages generally would be shipped on trailers designed specifically for the packaging used. For truck transportation, the maximum payload weight was considered to be about 20,000 kilograms (about 44,000 pounds), based on the Federal gross vehicle weight limit of 36,288 kilograms (80,000 pounds). However, large numbers of multitrailer combinations (known as longer-combination vehicles), with gross weights exceeding the Federal limit, are currently operating on rural roads and turnpikes in some states (FHWA 2003). For evaluation purposes, the load limit for the legal truck was based on the Federal gross vehicle weight.

Rail transport can be done with dedicated and/or general freight trains. For analysis purposes, use of a dedicated train was assumed. The payload weights for railcars range from 45,359 to 68,039 kilograms (100,000 to 150,000 pounds). A median payload weight of 54,431 kilograms (120,000 pounds) was used in this analysis.

[1] Based on the number of workers in the 200-East Area as of May 2007.

[2] The path is assumed to follow Route 45 within Hanford toward the 200 Areas.

The following types of waste and disposal destinations were evaluated for this *TC & WM EIS.*

Tank Closure

1. IHLW glass would be stored on site until disposition decisions are made and implemented.

2. ILAW glass would be disposed of on site.

3. TRU waste would be disposed of off site (at WIPP).

4. Supplemental technology (bulk vitrification, cast stone, or steam reforming) waste would be disposed of on site.

5. LLW, MLLW, and miscellaneous waste would be disposed of on site.

FFTF Decommissioning

1. Sodium metal would be neutralized (oxidized) either at Hanford or INL. If treatment is carried out at INL, the treated sodium hydroxide would be transported back to Hanford for use at the WTP.

2. RH-SCs and their sodium residuals would be treated either at Hanford or INL. If treatment is carried out at INL, the final waste would either be transported back to Hanford or sent to NTS for disposal. If treatment occurs at Hanford, the final waste would be disposed of on site.

3. LLW, MLLW, and miscellaneous waste would be disposed of on site.

Waste Management

1. Offsite LLW and MLLW from various DOE sources would be transported for disposal at Hanford.

2. Onsite LLW, MLLW, and miscellaneous waste would be disposed of on site.

The number of shipping containers per shipment was estimated based on the dimensions and weight of the shipping containers, the Transport Index,[3] and the transport vehicle dimensions and weight limits. The number of offsite shipments was estimated based on the following assumptions.

1. For transport of IHLW glass to onsite storage, each truck would transport one IHLW canister in a Type B SNF cask.

2. For transport to WIPP, contact-handled (CH)-TRU waste would be packaged in TRU Waste Package Transporter II (TRUPACT-II) containers, each holding fourteen 208-liter (55-gallon) drums, with three or six TRUPACT-II containers per truck or rail shipment. The RH-TRU waste would be packaged in a Type B cask (e.g., an RH-72B cask or CNS 10-160B), which can contain three 208-liter (55-gallon) drums, and transported—one cask per truck or two casks per rail.

[3] The Transport Index is a dimensionless number (rounded up to the next tenth) placed on the label of a package to designate the degree of control to be exercised by the carrier. Its value is equivalent to the maximum radiation level in millirem per hour at 1 meter (3.3 feet) from the package (10 CFR 71.4; 49 CFR 173.403).

3. For transport of sodium metal to INL, sodium metal would be shipped in sodium International Organization for Standardization (ISO) container tanks, each with a volume of about 15.1 cubic meters (4,000 gallons). Each truck would transport one ISO container. Sodium metal stored in a drum overpack would be transported in intermodal containers with 45 drums per truck transport. Two sodium ISO containers or two intermodal containers would be transported per railcar.

4. For transport of RH-SCs, each truck would transport one component in a specially designed Type B cask. Each railcar would transport two RH-SC casks. The same cask would be used to transport the treated RH-SCs back to Hanford, or to send them to NTS for disposal.

5. For transport of offsite LLW/MLLW to Hanford, each truck would transport eighty 208-liter (55-gallon) drums of CH-waste and between 10 and 14 drums of RH-waste in shielded Type A or Type B truck casks. Each railcar would transport two truck casks, or 160 drums.

The capacities of various onsite shipments per transport are as follows:

- One container of bulk vitrification waste on a heavy-haul truck
- Forty 208-liter (55-gallon) drums of LLW/MLLW or CH-TRU waste
- One ILAW glass canister
- Fourteen 208-liter (55-gallon) drums of RH-TRU waste
- One container of cast stone waste or two containers of sulfate grout
- Two shielded boxes or one roll-on/roll-off box of radioactive contaminated soils and/or equipment

Table H–4 summarizes the types of containers and their volumes and the number of containers in a shipment.

Table H–4. Waste Type and Container Characteristics

Waste Type[a]	Container	Volume per Container (cubic meters)	Number of Containers per Transport
IHLW glass	0.6-meter-diameter by 4.5-meter-long cylinder	1.19	1 per truck cask; 5 per rail cask
ILAW glass	1.22-meter-diameter by 2.3-meter-long cylinder	2.31	1 per truck shipment
Bulk vitrification glass	7.3- by 3.1- by 2.4-meter box	54.3	1 per truck shipment
Cast stone waste	2.7- by 2.7- by 1.5-meter box	10	1 per truck shipment
Steam reforming waste	1.5- by 1.5 -by 1.5-meter box	2.25	2 per truck shipment
TRU waste[b] (remote-handled)	208-liter drum	0.20	3 per cask: 1 cask per truck shipment; 2 casks per rail shipment[c]
TRU waste[b] (contact-handled)	208-liter drum	0.20	14 per TRUPACT-II: 3 TRUPACT-IIs per truck shipment; 6 TRUPACT-IIs per rail shipment[c]
TRU waste (contact- and remote-handled)	208-liter drum	0.20	40 per truck shipment (contact-handled), 14 per truck shipment in a shielded Type A or Type B cask (remote-handled)
LLW/MLLW[b, d]	208-liter drum	0.20	80, or 10 to 14 in a shielded Type B or Type A cask, respectively, per truck shipment; 160, or 2 casks per rail shipment[c]
Bulk sodium[b]	Sodium ISO container tank	15.1	1 per truck shipment; 2 per rail shipment[c]
Drummed sodium[e]	322-liter drum	0.32	45 per truck shipment; 90 per rail shipment[c]
Sodium hydroxide[f]	Caustic ISO container tank	14.1	1 per truck shipment; 2 per rail shipment[c]
Remote-handled special components[g]	Special cask	NA	1 per truck shipment; 2 per rail shipment[c]
Miscellaneous waste[h]	4.0- by 1.6- by 1.3-meter shielded box to 6.1- by 2.4- by 1.7-meter roll-on/roll-off box	4.6 to 20.0	2 shielded boxes, or 1 roll-on/roll-off box per truck shipment

[a] Transported on site unless specified otherwise.
[b] Transported off site after interim storage on site or brought to Hanford from offsite sources.
[c] Rail transports are for offsite shipments.
[d] Offsite waste transported to Hanford for disposal, including both contact-handled and remote-handled waste. Transport of remote-handled waste would involve use of shielded casks.
[e] This sodium is from the Sodium Reactor Experiment and is stored in 208-liter (55-gallon) drums overpacked in 322-liter (85-gallon) drums.
[f] Sodium hydroxide is a 50-percent caustic solution. Because it has a higher density than that of sodium metal, only about 13.2 cubic meters (3,500 gallons) of sodium hydroxide would be transported per ISO-container tank.
[g] Transport would occur in specially designed Type B casks.
[h] Includes radioactively contaminated equipment and soils that are generated during tank farm dismantling, cleanup, and closure.

Note: To convert cubic meters to cubic feet, multiply by 35.315; cubic meters to gallons, by 264.2; liters to gallons, by 0.26417; meters to feet, by 3.281.

Key: Hanford=Hanford Site; IHLW=immobilized high-level radioactive waste; ILAW=immobilized low-activity waste; ISO=International Organization for Standardization; LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste; NA=not available; TRU=transuranic; TRUPACT-II=Transuranic Waste Package Transporter II; WTP=Waste Treatment Plant.

H.5 INCIDENT-FREE TRANSPORTATION RISKS

H.5.1 Radiological Risk

During incident-free transportation of radioactive materials, a radiological dose results from exposure to the external radiation field that surrounds the shipping containers. The population dose is a function of the number of people exposed, their proximity to the containers and length of time of exposure, and the intensity of the radiation field surrounding the containers.

Radiological impacts were determined for crewmembers and the general population during incident-free transportation. For truck shipments, the drivers of the shipment vehicles are the crew. For rail shipments, the crew includes workers in close proximity to the shipping containers during inspection or classification of the railcars. The general population includes persons residing within 800 meters (0.5 miles) of the road or railway (off-link), persons sharing the road or railway (on-link), and persons at stops. Exposures to workers loading and unloading the shipments are not included in this analysis but are included in the occupational estimates for plant workers. Exposures to the inspectors and escorts (persons in a vehicle that follows or leads the shipment) are evaluated and presented separately.

Collective doses for the crew and general population were calculated using the RADTRAN 5 computer code (Neuhauser and Kanipe 2003). The radioactive material shipments were assigned an external dose rate based on their radiological characteristics. Offsite transportation of radioactive material in Type B casks has a defined dose limit of 10 millirem per hour at 2 meters (about 6.6 feet) from the cask (10 CFR 71.47), or about 14 millirem per hour at 1 meter (about 3.3 feet) from the cask. The RH- and CH-TRU waste package dose rates at 1 meter (about 3.3 feet) were assigned at 10 millirem per hour and 4 millirem per hour, respectively (DOE 1997). Dose rates for onsite transportation packages could be more than 10 millirem per hour at 2 meters (about 6.6 feet), provided that the roads are closed to the public. Dose rates at 1 meter (about 3.3 feet) for the ILAW glass and the cast stone, steam-reformed, and bulk-vitrified glass waste containers were estimated based on the cesium-137, cobalt-60, and europium-154 inventory per container. It was assumed that sufficient shielding would be used for each container to meet the Hanford disposal dose rate requirement (surface dose rate less than 200 millirem per hour). Based on the maximum potential inventories of the three isotopes listed above in each container, a dose rate of 14, 80, 63, and 60 millirem per hour at 1 meter (about 3.3 feet) was assessed for the ILAW glass, cast stone waste, steam-reformed waste, and bulk-vitrified glass, respectively.

Dose rates at 1 meter (about 3.3 feet) for the sodium and sodium hydroxide tanks were estimated to be about 2 and 1 millirem per hour, respectively. The 1-meter dose rate for the RH-SCs in Type B casks was assumed to be 14 millirem per hour. Dose rates at 1 meter for the CH-offsite LLW and MLLW and RH-offsite LLW and MLLW were estimated to be 3 and 6 millirem per hour, respectively. Note that the RH-offsite waste would be transported in shielded Type A or Type B casks, as required.

To calculate the collective dose, a unit risk factor was developed to estimate the impact of transporting one shipment of radioactive material over a unit distance of travel in a given population density zone. Table H–5 provides examples of unit risk factors from transport of a generic radioactive waste package with a Transport Index of 1 (i.e., a dose rate of 1 millirem per hour at 1 meter [3.3 feet] from the surface of the shipping container or the conveyance) by truck and rail. This table provides a perspective to the public on risk values from the movement of radioactive materials in truck and rail packages over 1 kilometer (0.6214 miles). The values in Table H–5 reflect assumptions regarding public shielding afforded by the general housing structure within each population zone, which are major contributing factors in calculating the dose, time, and distance to an exposed individual.

Unit risk factors were developed using RADTRAN 5 and its default data on the basis of travel on interstate highways and freeways, as required by DOT regulations (49 CFR 171-177) for highway route controlled quantities of radioactive material within rural, suburban, and urban population zones. In addition, the analysis assumed that 10 percent of the time, travel through suburban and urban zones would encounter rush-hour conditions, leading to lower average speed and higher traffic density. The unit risk factors were combined with routing information, such as the shipment distances in various population density zones, to determine the risk from a single shipment (shipment risk factor) between a given origin and destination.

The radiological risks from transporting the waste were estimated in terms of the number of LCFs among the crew and the exposed population. A health risk conversion factor of 0.0006 LCFs per person-rem of exposure was used for both the workers and the public (DOE 2003).

Table H–5. Incident-Free Unit Risk Factors for a Dose Rate of 1 Millirem per Hour at 1 Meter (3.3 Feet) from the Shipping Container for Truck and Rail Shipments

Mode	Exposure Group	Unit Risk Factors[a]		
		Rural	Suburban[b]	Urban[b]
Truck	Occupational[c] (person-rem per kilometer)	5.33×10^{-6}	5.86×10^{-6}	5.86×10^{-6}
	General population			
	Off-link[d] (person-rem per kilometer per person per square kilometer)	2.62×10^{-9}	2.50×10^{-9}	5.18×10^{-11}
	On-link[e] (person-rem per kilometer)	7.21×10^{-7}	1.79×10^{-6}	5.66×10^{-6}
	Stops (person-rem per kilometer per person per square kilometer)	2.30×10^{-10}	2.30×10^{-10}	2.30×10^{-10}
	Escorts[f] (person-rem per kilometer)	2.42×10^{-7}	2.55×10^{-7}	2.55×10^{-7}
Rail	Occupational[g] (person-rem per kilometer)	2.10×10^{-7}	2.10×10^{-7}	2.10×10^{-7}
	General population			
	Off-link[d] (person-rem per kilometer per person per square kilometer)	3.52×10^{-9}	4.90×10^{-9}	1.69×10^{-10}
	On-link[e] (person-rem per kilometer)	8.23×10^{-9}	1.06×10^{-6}	2.94×10^{-7}
	Stops (person-rem per kilometer per person per square kilometer)	8.10×10^{-10}	8.10×10^{-10}	8.10×10^{-10}
	Escorts[h] (person-rem per kilometer)	1.57×10^{-6}	2.52×10^{-6}	4.21×10^{-6}

[a] The methodology, equations, and data used to develop the unit risk factors are discussed in the *RADTRAN 5 User Guide* (Neuhauser and Kanipe 2003). The risk factors provided here are for truck and rail waste packages (i.e., casks) with the following characteristic lengths and diameters: 5.2 meters (~17.1 feet) in length by 1.0 meter (3.3 feet) in diameter for a truck cask and 5.06 meters (16.6 feet) in length by 2.0 meters (6.6 feet) in diameter for a rail cask. Because the characteristics of transuranic (TRU) waste shipments are different from those used here, the contact-handled TRU waste shipment risk factors would be higher than the values given here by factors of 1.39 and 1.76 for the population dose and crew dose, respectively.

[b] Ten percent of vehicles traveling within these zones encounter rush-hour traffic with a lower speed and a higher traffic density.

[c] The maximum dose in the truck cabin (crew dose) is 2 millirem per hour (10 CFR 71.47) unless the crew includes a trained radiation worker, which would administratively limit the annual dose to 2 rem per year (DOE Standard 1098-99).

[d] Off-link general population refers to persons within 800 meters (0.5 miles) of the road or railway. The difference in doses between the rural, suburban, and urban populations is due to the assumptions on the shielding factors applicable in various zones.

[e] On-link general population refers to persons sharing the road or railway.

[f] Escorts are two persons in a vehicle that follows or leads the truck by 60 meters (about 200 feet). The dose to passengers in this vehicle is estimated to be 0.15 millirem per hour for a cask at the regulation dose limit (DOE 2002a).

[g] The nonlinear component of the incident-free rail dose for crewmembers because of railcar inspections and classifications, 0.000233 person-rem per shipment, is not included in the unit risk factors. The *RADTRAN 5 Technical Manual*, Appendix B (Neuhauser, Kanipe, and Weiner 2000), contains an explanation of the rail exposure model.

[h] These escorts (two persons) are at a distance of 30 meters (about 100 feet) from the end of the shipping cask. The dose to each escort is estimated to be 0.71 millirem per hour for a cask at the regulation dose limit (DOE 2002a).

Note: To convert kilometers to miles, multiply by 0.6214; square kilometers to square miles, by 0.3861.

H.5.2 Nonradiological Risk

Nonradiological risks (vehicle-related health risks) resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during shipment and are independent of the radioactive nature of the shipment. The health endpoint assessed under incident-free transport conditions is the excess latent mortality due to inhalation of vehicle emissions.

Unit risk factors for pollutant inhalation in terms of mortality have been generated (Rao, Wilmot, and Luna 1982). These unit risk factors account for potential fatalities from emissions of particulates and sulfur dioxide, but they are applicable only to the urban population zone, which is a small fraction of the total transport distance. The emergence of considerable data regarding minimum threshold values for health risks from chemical constituents of vehicle exhaust has made linear extrapolation to estimate the risks from lower exposure levels to vehicle emissions untenable. Calculated risks should be compared with a standard or other comparable risks to put the risks in perspective, but this is not possible with emission risks. This calculation has been dropped from RADTRAN in its recent revision (Neuhauser, Kanipe, and Weiner 2000). Therefore, no risk factors were assigned to the vehicle emissions analyzed in this *TC & WM EIS*.

H.5.3 Maximally Exposed Individual Exposure Scenarios

The MEI doses for routine offsite transportation were estimated for both transportation workers and members of the general public.

For truck shipments, three hypothetical scenarios were evaluated to determine the MEI in the general population (DOE 2002a).

- A person caught in traffic and located 1.2 meters (4 feet) from the surface of the shipping container for 30 minutes
- A resident living 30 meters (98 feet) from the highway used to transport the shipping container
- A service station worker working at a distance of 16 meters (52 feet) from the shipping container for 50 minutes

The hypothetical MEI doses were accumulated over a single year for all transportation shipments. However, for the scenario involving an individual caught in traffic next to a shipping container, the radiological exposures were calculated for only one event because it was considered unlikely that the same individual would be caught in traffic next to all containers for all shipments. For truck shipments, the maximally exposed transportation worker would be the driver, who was assumed to have been trained as a radiation worker and to drive shipments for up to 2,000 hours per year, resulting in an accumulated exposure of 2 rem per year. The maximum exposure rate for a member of a truck crew who is not a radiation worker would be 2 millirem per hour (10 CFR 71.47).

Three hypothetical scenarios were also evaluated for railcar shipments.

- A rail yard worker working at a distance of 10 meters (33 feet) from the shipping container for 2 hours
- A resident living 30 meters (98 feet) from the rail line where the shipping container is being transported
- A resident living 200 meters (656 feet) from a rail stop during classification and inspection for 20 hours

For rail shipments, the maximally exposed transportation worker would be an individual inspecting the cargo at 1 meter (3.3 feet) from the shipping container for 1 hour.

H.6 TRANSPORTATION ACCIDENT RISKS AND MAXIMUM REASONABLY FORESEEABLE CONSEQUENCES

H.6.1 Methodology

Offsite transportation accident analysis considers the impacts of accidents during transportation of waste by truck or rail. Under accident conditions, impacts on human health and the environment could result from the release and dispersal of radioactive material. Transportation accident impacts were assessed using accident analysis methodology developed by NRC. This section provides an overview of the methodologies; detailed descriptions of various methodologies are found in NUREG-0170, *Radioactive Material Transport Study*; NUREG/CR-4829, *Modal Study*; and NUREG/CR-6672, *Reexamination Study* (NRC 1977; Fischer et al. 1987; Sprung et al. 2000). Accidents that could potentially breach the shipping container were represented by a spectrum of accident severities and radioactive release conditions. Historically, most transportation accidents involving radioactive materials resulted in little or no release of radioactive material from the shipping container. Consequently, the analysis of accident risks accounted for a spectrum of accidents ranging from high-probability accidents of low severity to hypothetical high-severity accidents that have a low probability. The accident analysis also calculated the probabilities and consequences of this spectrum of accidents.

Two types of analysis were performed to provide DOE and the public with a reasonable assessment of potential accident impacts of radioactive waste transportation. First, an accident risk assessment was performed to account for the probabilities and consequences of a spectrum of potential accident severities using a methodology developed by NRC (NRC 1977; Fischer et al. 1987; Sprung et al. 2000). For the spectrum of accidents considered in the analysis, accident consequences in terms of the collective "dose risk" to the population within 80 kilometers (50 miles) were determined using the RADTRAN 5 computer program (Neuhauser and Kanipe 2003). The RADTRAN 5 code sums the product of consequences and probability over all accident severity categories to obtain a probability-weighted risk value referred to in this appendix as the "dose risk," which is expressed in units of person-rem. Second, to represent the maximum reasonably foreseeable impacts on individuals and populations should an accident occur, the maximum radiological consequences were calculated in an urban (or suburban) population zone for an accidental release with a likelihood of occurrence of greater than 1 in 10 million per year using the RISKIND computer program (Yuan et al. 1995).

For accidents in which the waste container or the cask shielding is not damaged, population and individual radiation exposure from the waste package was evaluated for the duration of time needed to recover and restart shipment. It was assumed that it would take 12 hours to recover from an accident. During this period, no individual would remain close to the cask. An individual (first responder) could stay at a location 2 to 10 meters (3.3 to 33 feet) from the package, at a position where the dose rate would be the highest, for 30 minutes in a loss-of-shielding accident and 1 hour for other accidents with no release (DOE 2002a). For accidents leading to loss of cask shielding, a method similar to that provided in NUREG/CR-6672, *Reexamination Study,* was used (DOE 2002a; Sprung et al. 2000). The collective dose over all segments of the transportation routes was evaluated for an affected population located up to a distance of 800 meters (0.5 miles) from the accident location. This dose would be an external dose, approximately inversely proportional to the square of the distance of the affected population from the accident. Any additional dose to those residing beyond 800 meters (0.5 miles) from the accident would be negligible.

H.6.2 Accident Rates

For the calculation of accident risks, vehicle accident and fatality rates were taken from data provided in *State-Level Accident Rates of Surface Freight Transportation: A Reexamination* (Saricks and Tompkins 1999). Accident rates are generically defined as the number of accident involvements (or fatalities) in a given year per unit of travel in that same year. Therefore, the rate is a fractional value, with the accident involvement count as the numerator of the fraction and vehicular activity (total travel distance in truck kilometers) as the denominator. Accident rates are generally determined for a multiyear period. For assessment purposes, the total number of expected accidents or fatalities was calculated by multiplying the total shipment distance for a specific case by the appropriate accident or fatality rate.

For truck transportation, the rates presented here are specifically for heavy-haul combination trucks involved in interstate commerce (Saricks and Tompkins 1999). Heavy-haul combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy-haul combination trucks are typically used for radioactive material shipments. The truck accident rates were computed for each state based on statistics compiled by the DOT Federal Highway Administration, Office of Motor Carriers, from 1994 to 1996. A fatality caused by an accident is defined as the death of a member of the public who is killed instantly or dies within 30 days due to injuries sustained in the accident.

For offsite truck transportation, separate accident rates and accident fatality risks were used for rural, suburban, and urban population zones. The values selected are the mean accident and fatality rates under interstate, primary, and total categories for rural, suburban, and urban population zones, respectively (Saricks and Tompkins 1999). The accident rates are 3.15, 3.52, and 3.66 per 10 million truck kilometers, and the fatality rates are 0.88, 1.49, and 2.32 per 100 million truck kilometers for rural, suburban, and urban zones, respectively. For rail transportation, the accident and fatality rates are the mean value rates applicable to all population zones. The rates used in this analysis are 2.74 accidents per 10 million railcar kilometers and 7.82 fatalities per 100 million railcar kilometers. The national mean values for truck and rail accident and fatality rates were used because these values are less prone to the uncertainties associated with the state-level data that can be under-reported or have a small data set. In addition, the analyzed routes are considered representative and are not necessarily the ones that would be used in the future. Further, the use of national mean values would result in conservative estimates on the number of accidents and fatalities per trip.

For onsite and local/regional transport, Washington State accident and fatality rates were used—1.23 accidents per 10 million truck kilometers and 0.83 fatalities per 100 million truck kilometers (Saricks and Tompkins 1999).

H.6.3 Accident Severity Categories and Conditional Probabilities

Accident severity categories for potential radioactive waste transportation accidents are described in NUREG-0170, *Radioactive Material Transport Study* (NRC 1977), which addresses general radioactive waste transportation risks, as well as in NUREG/CR-4829, *Modal Study* (Fischer et al. 1987), and NUREG/CR-6672, *Reexamination Study* (Sprung et al. 2000), both of which address SNF transportation risks (the *Reexamination Study* is a refinement of the *Modal Study*). The method described in NUREG/CR-6672 is applicable to transportation of IHLW glass in a Type B SNF cask. The accident severity categories presented in NUREG-0170 are applicable to onsite waste transport. In addition to these reports, DOE's Richland Operations Office has developed the *Safety Evaluation Report, Hanford Transportation Safety Document*, a site-specific transportation safety document for determining onsite transportation risks (DOE 2002b). This document applied modeling from NUREG/CR-6672 to estimate site-specific severity probabilities.

NUREG-0170, *Radioactive Material Transport Study* (NRC 1977), originally was used to estimate the conditional probabilities associated with accidents involving transportation of radioactive materials. NUREG/CR-4829, *Modal Study*, and NUREG/CR-6672, *Reexamination Study* (Fischer et al. 1987; Sprung et al. 2000), were initiatives taken by NRC to refine more precisely the analysis presented in the NUREG-0170 for SNF shipping casks.

Whereas the analysis in NUREG-0170, *Radioactive Material Transport Study*, was primarily performed using the best engineering judgments and presumptions concerning cask response, later studies relied on sophisticated structural and thermal engineering analysis and a probabilistic assessment of the conditions that could be experienced in severe transportation accidents. These results were based on representative SNF casks that were assumed to be designed, manufactured, operated, and maintained according to national codes and standards. The design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR 71. NUREG-0170 is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

In both NUREG/CR-4829, *Modal Study*, and NUREG/CR-6672, *Reexamination Study*, potential accident damage to a cask is categorized according to the magnitude of the mechanical forces (impact) and thermal forces (fire) to which a cask may be subjected during an accident. Because all accidents can be described in these terms, severity is independent of the specific accident sequence. In other words, any sequence of events that results in an accident in which a cask is subjected to forces within a certain range of values is assigned to the accident severity region associated with that range. The accident severity scheme is designed to take into account all potential foreseeable transportation accidents, including accidents with low probability but high consequences and those with high probability but low consequences.

As discussed earlier, the accident consequence assessment considers only the potential impacts of the most severe transportation accidents. In terms of risk, the severity of an accident must be viewed in terms of potential radiological consequences, which are directly proportional to the fraction of the radioactive material within a cask that is released to the environment during the accident. Although accident severity regions span the entire range of mechanical and thermal accident loads, they are grouped into accident categories that can be characterized by a single set of release fractions and, therefore, are considered together in the accident consequence assessment. The accident category severity fraction is the sum of all conditional probabilities in that accident category.

For the accident risk assessment, accident "dose risk" was generically defined as the product of the consequences of an accident and the probability of the occurrence of that accident, an approach consistent with the methodology used by the RADTRAN 5 computer code. The RADTRAN 5 code sums the product of consequences and probability over all accident severity categories to obtain a probability-weighted risk value referred to in this appendix as "dose risk," which is expressed in units of person-rem.

H.6.4 Atmospheric Conditions

Because it is impossible to predict the specific location of an offsite transportation accident, generic atmospheric conditions were selected for the risk and consequence assessments. On the basis of observations from National Weather Service surface meteorological stations at over 177 locations in the United States, on an annual average, neutral conditions (Pasquill Stability Classes C and D) occur 58.5 percent of the time, and stable (Pasquill Stability Classes E, F, and G) and unstable (Pasquill Stability Classes A and B) conditions occur 33.5 percent and 8 percent of the time, respectively (DOE 2002a). Neutral weather conditions predominate in each season, but most frequently in winter (nearly 60 percent of the observations).

Neutral weather conditions (Pasquill Stability Class D) compose the most frequently occurring atmospheric stability condition in the United States, and are thus most likely to be present in the event of an accident involving a radioactive waste shipment. Neutral weather conditions are typified by moderate windspeeds, vertical mixing within the atmosphere, and good dispersion of atmospheric contaminants. Stable weather conditions are typified by low windspeeds, very little vertical mixing within the atmosphere, and poor dispersion of atmospheric contaminants. The atmospheric condition used in RADTRAN 5 is an average weather condition that corresponds to a stability class spread between Class D (for near distance) and Class E (for farther distance).

The accident consequences for the maximum reasonably foreseeable accident (an accident with a likelihood of occurrence of greater than 1 in 10 million per year) were assessed under both stable (Class F with a windspeed of 1 meter [3.3 feet] per second) and neutral (Class D with a windspeed of 4 meters [13 feet] per second) atmospheric conditions. These calculations estimate the potential doses to an individual and a population within a zone, respectively. The individual dose would represent the MEI in an accident under weather conditions that maximize the dose (stable condition, with minimum diffusion and dilution). The population dose would represent an average weather condition.

H.6.5 Radioactive Release Characteristics

Radiological consequences were calculated by assigning radionuclide release fractions on the basis of the type of waste, the type of shipping container, and the accident severity category. The release fraction is defined as the fraction of radioactivity in the container that could be released to the atmosphere due to an accident with a given severity. Release fractions vary according to the waste type and the physical or chemical properties of the radioisotopes. Most solid radionuclides are nonvolatile and, therefore, are relatively nondispersible.

Representative release fractions were developed for each waste and container type on the basis of DOE and NRC reports (DOE 2002c; DOE Handbook 3010-94; NRC 1977; Sprung et al. 2000). The severity categories and corresponding release fractions provided in these documents cover a range of accidents from no impact (zero speed) to impacts at a speed in excess of 193 kilometers (120 miles) per hour onto an unyielding surface. Accidents that could occur at Hanford would have lower impacts due to lower local speed limits and site-specific road and surface characteristics.

For the IHLW in a Type B SNF cask, the particulate release fractions for vitrified waste described in the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (*Yucca Mountain FEIS*) (DOE 2002a) were used. For the ILAW glass (including bulk vitrification and cast stone), the particulate release fractions for the severity categories corresponding to the severity accidents listed in NUREG-0170, *Radioactive Material Transport Study*, were used (DOE 2002c; NRC 1977). The aerosolized fractions for these waste types were assumed to be in the respirable range. For waste transported in Type A containers (e.g., a 208-liter [55-gallon] drum), the fractions of radioactive material released from the shipping container were based on recommended values from NUREG-0170 (NRC 1977). The NUREG-0170 values were multiplied by an aerosolized fraction to estimate the amount of material dispersed into the atmosphere. For CH- and RH-TRU waste, the release fractions corresponding to the NUREG-0170 severity categories and adapted in the *WIPP SEIS-II* were used (DOE 1997, 2002c).

For transport of sodium metal and sodium hydroxide solution in ISO container tanks, the severity fractions and associated release fractions were based on accident statistics from the National Highway Traffic Safety Administration (DOT 2002, 2004–2006) and recommended values from NUREG-0170, *Radioactive Material Transport Study* (NRC 1977), and *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE Handbook 3010-94). Human health impacts due to toxic chemical exposures from sodium fires are analyzed in Appendix K; two of the analyses involve quantities of sodium similar to those expected to be present in a transportation accident. The potential toxic impacts of a transportation accident that produces a sodium fire are therefore expected to be comparable to those presented in Appendix K.

H.6.6 Acts of Sabotage or Terrorism

In the aftermath of the tragic events of September 11, 2001, DOE is continuing to assess potential measures to minimize the risk or potential consequences of radiological sabotage. While it is not possible to determine terrorists' motives and targets with certainty, DOE considers the threat of terrorist attack to be real and makes all efforts to reduce any vulnerability to this threat. DOE considers, evaluates, and plans for potential terrorist attacks during transportation and storage of radioactive materials. The details of any postulated terrorist attack, as well as DOE's plans for the security of its facilities and its terrorist countermeasures, are classified.

Nevertheless, DOE has evaluated the impacts of acts of sabotage and terrorism for SNF and HLW shipments (DOE 1996, 2002a). The spectrum of acts considered range from direct attack on the cask from afar to hijacking and exploding the shipping cask in an urban area. Both of these actions would result in damaging the cask and its contents and releasing radioactive materials. The fraction of the materials released depends on the nature of the attack (type of explosive or weapons used). The analyses of sabotage events described in the *Yucca Mountain FEIS* (DOE 2002a) were considered enveloping analyses for this *TC & WM EIS*. The events were assumed to involve either a truck- or rail-sized cask containing light-water reactor SNF. The consequences of such acts were calculated to result in an MEI dose of 40 to 110 rem (at 140 meters [460 feet]) for events involving a truck- or rail-sized cask, respectively. These events would lead to a 2 to 7 percent increase in the risk of fatal latent cancer to an MEI (DOE 2002a). The quantity of radioactive materials transported under all *TC & WM EIS* alternatives would be less than those considered in the *Yucca Mountain FEIS* (DOE 2002a) and its supplemental EIS (DOE 2008). Therefore, estimates of risks provided in the *Yucca Mountain FEIS* envelope the risks from an act of sabotage or terrorism involving radioactive material transported under all alternatives analyzed in this *TC & WM EIS*.

H.7 RISK ANALYSIS RESULTS

Per-shipment risk factors were calculated for collective populations of exposed persons and the crew for all anticipated routes and shipment configurations. Radiological risks are presented in doses per shipment for each unique route, material, and container combination. Per-shipment radiological risk factors for incident-free transportation and accident conditions are presented in Table H–6. For incident-free transportation, both dose and LCF risk factors are provided for the crew and exposed population. The radiological risks would result from potential exposure to external radiation emanating from the packaged waste. The exposed population would include the off-link public (people living along the route), on-link public (pedestrian and car occupants along the route) and the public at rest and fuel stops. For onsite shipments, the populations at rest and fuel stops are set at zero because a truck is not expected to stop during shipments that take less than an hour.

For transportation accidents, both radiological (in terms of potential LCFs among the exposed population) and nonradiological (in terms of number of traffic fatalities) risk factors are given. The LCF represents the number of additional latent fatal cancers among the exposed population. In an accident condition, the population would receive a direct dose if the package is not breached. If the package is breached, the population would receive an additional dose from released radioactive materials. For accidents with no release, the analysis conservatively assumed that it would take about 12 hours to remove the package and/or vehicle from the accident area (DOE 2002a). Accidents leading to loss of cask shielding would only be applicable to those shipments that use lead shielded casks, such as shipments of IHLW glass and

RH-waste. Onsite accidents would not lead to loss of shielding due to lower vehicle velocity and accident impacts.

As indicated in Table H–6, all risk factors are less than one, meaning that no LCF or traffic fatalities are expected to occur during each transport. For example, the risk factors for the truck crew and the population from transporting one truck shipment of RH-TRU waste to WIPP are 1.07×10^{-4} and 3.21×10^{-5} LCFs, respectively. These values mean that there is a chance of 1 in 9,350 that an individual from a truck crew would develop a latent fatal cancer from exposure to radiation during one shipment of RH-TRU waste to WIPP and a chance of 1 in 31,150 that the exposed population residing along the transport route would experience an additional latent fatal cancer.

Table H–6. Risk Factors per Shipment of Radioactive Waste

Waste Material (mode of transport)	Transport Destination	Incident-Free				Accident	
		Crew Dose (person-rem)	Crew Risk (LCFs)	Population Dose (person-rem)	Population Risk (LCFs)	Rad. Risk (LCFs)	Nonrad. Risk (traffic fatalities)
Tank Closure							
RH-TRU waste (T)[a]	WIPP	1.78×10^{-1}	1.07×10^{-4}	5.35×10^{-2}	3.21×10^{-5}	2.52×10^{-7}	6.10×10^{-5}
CH-TRU waste (T)[a]	WIPP	1.17×10^{-1}	7.03×10^{-5}	4.24×10^{-2}	2.55×10^{-5}	7.64×10^{-9}	6.10×10^{-5}
ILAW glass (T)	Hanford (on site)	2.7×10^{-3}	1.62×10^{-6}	7.51×10^{-4}	4.51×10^{-7}	1.12×10^{-16}	2.82×10^{-7}
Bulk vitrification glass (T)	Hanford (on site)	2.10×10^{-2}	1.26×10^{-5}	2.22×10^{-2}	1.33×10^{-5}	2.69×10^{-14}	2.82×10^{-7}
Cast stone waste (T)	Hanford (on site)	1.61×10^{-2}	9.64×10^{-6}	2.26×10^{-3}	1.36×10^{-6}	6.97×10^{-15}	2.82×10^{-7}
Steam reforming waste (T)	Hanford (on site)	8.78×10^{-3}	5.27×10^{-6}	2.14×10^{-3}	1.28×10^{-6}	1.79×10^{-15}	2.82×10^{-7}
Sulfate grout (T)	Hanford (on site)	6.15×10^{-4}	3.69×10^{-7}	1.36×10^{-4}	8.16×10^{-8}	1.26×10^{-16}	2.82×10^{-7}
IHLW glass (T)[b]	Hanford (on site)	8.81×10^{-4}	5.28×10^{-7}	2.59×10^{-4}	1.56×10^{-7}	1.48×10^{-16}	1.41×10^{-7}
RH-TRU waste (R)[c]	WIPP	1.20×10^{-2}	7.20×10^{-6}	2.51×10^{-2}	1.50×10^{-5}	3.23×10^{-8}	5.52×10^{-4}
CH-TRU waste (R)[c]	WIPP	6.73×10^{-3}	4.04×10^{-6}	1.97×10^{-2}	1.18×10^{-5}	2.35×10^{-9}	5.52×10^{-4}
Miscellaneous waste (T)[d]	Hanford (on site)	1.96×10^{-3}	1.18×10^{-6}	6.68×10^{-5}	4.01×10^{-8}	2.05×10^{-10}	2.82×10^{-7}
RH-TRU waste (T)	Hanford (on site)	4.58×10^{-3}	2.75×10^{-6}	1.60×10^{-4}	9.57×10^{-8}	6.54×10^{-10}	2.82×10^{-7}
CH-TRU waste (T)	Hanford (on site)	1.19×10^{-3}	7.12×10^{-7}	2.14×10^{-4}	1.29×10^{-7}	2.10×10^{-9}	2.82×10^{-7}
Fast Flux Test Facility							
Sodium metal (T)	INL	2.03×10^{-2}	1.22×10^{-5}	5.45×10^{-3}	3.27×10^{-6}	5.29×10^{-10}	1.92×10^{-5}
Sodium metal (R)	INL	1.81×10^{-3}	1.09×10^{-6}	3.57×10^{-3}	2.14×10^{-6}	9.02×10^{-10}	1.66×10^{-4}
Caustic (T)	Hanford	1.01×10^{-2}	6.08×10^{-6}	2.72×10^{-3}	1.63×10^{-6}	1.27×10^{-12}	1.92×10^{-5}
Caustic (R)	Hanford	9.04×10^{-4}	5.42×10^{-7}	1.78×10^{-3}	1.07×10^{-6}	2.16×10^{-12}	1.66×10^{-4}
RH special components (T)	INL	7.83×10^{-2}	4.70×10^{-5}	3.24×10^{-2}	1.94×10^{-5}	4.42×10^{-12}	1.92×10^{-5}
RH special components (R)	INL	6.37×10^{-3}	3.82×10^{-6}	1.79×10^{-2}	1.08×10^{-5}	3.77×10^{-12}	1.66×10^{-4}
Treated special components (T)[e]	NTS	9.58×10^{-2}	5.75×10^{-5}	4.06×10^{-2}	2.44×10^{-5}	9.79×10^{-12}	2.45×10^{-5}

Table H–6. Risk Factors per Shipment of Radioactive Waste *(continued)*

Waste Material (mode of transport)	Transport Destination	Incident-Free				Accident	
		Crew Dose (person-rem)	Crew Risk (LCFs)	Population Dose (person-rem)	Population Risk (LCFs)	Rad. Risk (LCFs)	Nonrad. Risk (traffic fatalities)
Fast Flux Test Facility *(continued)*							
Treated special components (R)[e]	NTS	7.52×10^{-3}	4.51×10^{-6}	2.01×10^{-2}	1.21×10^{-5}	5.62×10^{-12}	2.28×10^{-4}
Caustic (T)[f]	Hanford	1.42×10^{-1}	8.52×10^{-5}	3.81×10^{-2}	2.29×10^{-5}	4.47×10^{-8}	1.92×10^{-5}
Sodium metal	Hanford (on site)	1.60×10^{-3}	9.60×10^{-7}	1.72×10^{-4}	1.03×10^{-7}	2.70×10^{-13}	6.14×10^{-7}
Caustic	Hanford (on site)	4.93×10^{-4}	2.96×10^{-7}	4.70×10^{-5}	2.82×10^{-8}	3.59×10^{-15}	3.98×10^{-7}
Special components	Hanford (on site)	6.14×10^{-3}	3.69×10^{-6}	1.02×10^{-3}	6.14×10^{-7}	1.25×10^{-14}	6.14×10^{-7}
Reactor vessel	Hanford (on site)	1.95×10^{-3}	1.17×10^{-6}	1.67×10^{-3}	1.00×10^{-6}	N/A	N/A
Waste Management							
LLW (T)[g]	Hanford	2.21×10^{-1}	1.33×10^{-4}	6.55×10^{-2}	3.93×10^{-5}	1.29×10^{-8}	1.0×10^{-4}
LLW (R)[g]	Hanford	8.36×10^{-3}	5.02×10^{-6}	2.14×10^{-2}	1.28×10^{-5}	9.06×10^{-9}	7.63×10^{-4}
MLLW (T)[g]	Hanford	1.61×10^{-1}	9.66×10^{-5}	6.03×10^{-2}	3.62×10^{-5}	2.09×10^{-8}	9.27×10^{-5}
MLLW (R)[g]	Hanford	5.68×10^{-3}	3.41×10^{-6}	2.01×10^{-2}	1.21×10^{-5}	2.86×10^{-8}	7.45×10^{-4}
LLW[h]	Hanford (on site)	1.25×10^{-2}	7.48×10^{-6}	3.06×10^{-4}	1.84×10^{-7}	3.81×10^{-12}	9.15×10^{-7}
MLLW[h]	Hanford (on site)	8.08×10^{-4}	4.85×10^{-7}	1.03×10^{-4}	6.17×10^{-8}	1.12×10^{-11}	9.15×10^{-7}

[a] Truck is the current mode of transporting TRU waste to WIPP.
[b] IHLW transport to an onsite storage location occurs within the 200 Areas.
[c] Rail is the future/reserved mode of transporting TRU waste to WIPP.
[d] Includes radioactively contaminated equipment, dirt, and ancillary equipment placed in shielded boxes during tank closure.
[e] Impacts of transport of treated components to Hanford would be similar to those of transport to INL.
[f] Reflects the transport of caustics generated from treatment of remote-handled special components.
[g] These values reflect the maximum impacts of transport of radioactive waste from offsite sources (i.e., Argonne National Laboratory-East, Brookhaven National Laboratory, INL, Los Alamos National Laboratory, Oak Ridge National Laboratory, Paducah, Portsmouth, Savannah River Site, and West Valley Demonstration Project) to Hanford.
[h] These values reflect maximum impacts of transport of onsite waste.

Key: CH=contact-handled; Hanford=Hanford Site; IHLW=immobilized high-level radioactive waste; ILAW=immobilized low-activity waste; INL=Idaho National Laboratory; LCF=latent cancer fatality; LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste; N/A=not applicable, no accident was considered; Nonrad.=nonradiological; NTS=Nevada Test Site; R=rail; Rad.=radiological; RH=remote-handled; T=truck; TRU=transuranic; WIPP=Waste Isolation Pilot Plant.

Both the radiological dose risk factor and nonradiological risk factor for transportation accidents are also presented in Table H–6. The radiological and nonradiological accident risk factors are provided in terms of potential fatalities per shipment. The radiological risks are presented in terms of LCFs. For the population, the radiological risks were calculated by multiplying the accident dose risks by the health risk factor of 0.0006 LCFs per person-rem of exposure. As stated in Section H.6.3, the accident dose is called "dose risk" because the values incorporate the spectrum of accident severity probabilities and associated consequences (e.g., dose). The radiological accident doses are very low because accident severity probabilities (i.e., the likelihood of accidents leading to confinement breach of a shipping cask and release of its content) are very small and, although persons reside within in an 80-kilometer (50-mile) radius of the road, they are generally quite far from the road. Because RADTRAN 5 uses an assumption of homogeneous population from the road out to 80 kilometers (50 miles), it greatly overestimates the actual doses. The nonradiological risk factors are nonoccupational traffic fatalities resulting from transportation accidents.

H.7.1 Tank Closure Alternatives

Table H–7 provides the estimated number of shipments for various wastes under all Tank Closure alternatives. The numbers of shipments were calculated using the estimated waste volumes and packagings for each waste type given in Appendix D, Section D.1, as well as the waste container and shipment characteristics provided in Table H–2. The offsite shipment values were based on an assumption that RH-TRU waste would be transported by truck. This assumption is consistent with the modes of transportation analyzed for the Preferred Alternative in the *WIPP SEIS-II* (DOE 1997) and selected in the WIPP SEIS-II Record of Decision (63 FR 3624).

Table H–7. Tank Closure Alternatives – Estimates of Number of Radioactive Waste Shipments

Alternative	Number of Shipments									
	Offsite Shipments		Onsite Shipments							
	CH-TRU Waste[a]	RH-TRU Waste[a]	IHLW[b]	ILAW Glass	Bulk Vit. Glass	Cast Stone Waste	Steam Reforming Waste	CH-TRU Waste	RH-TRU Waste	Other Wastes[c]
2A	N/A	N/A	12,340	92,250	N/A	N/A	N/A	N/A	N/A	30
2B	N/A	N/A	12,340	92,250	N/A	N/A	N/A	N/A	N/A	23,581
3A	170	3,397	9,040	28,510	6,030	N/A	N/A	178	728	23,558
3B	170	3,397	9,040	28,510	N/A	23,270	N/A	178	728	23,558
3C	170	3,397	9,040	28,510	N/A	N/A	57,980	178	728	23,558
4	172	3,427	11,140	28,730	2,380	14,380	N/A	180	735	85,573
5	155	3,090	8,140	31,100	2,150	8,060[d]	N/A	162	663	10
6A, Base Case	N/A	N/A	171,670	670	N/A	N/A	N/A	N/A	N/A	254,559
6A, Option Case	N/A	N/A	171,670	18,290	N/A	N/A	N/A	N/A	N/A	254,680
6B, Base Case	N/A	N/A	12,340	93,670	N/A	N/A	N/A	N/A	N/A	254,581
6B, Option Case	N/A	N/A	12,340	111,290	N/A	N/A	N/A	N/A	N/A	254,658
6C	N/A	N/A	12,340	92,250	N/A	N/A	N/A	N/A	N/A	23,581

[a] Values are for truck shipments. Rail shipments are one-half of the values given.
[b] The IHLW canisters include 340 cesium and strontium high-level radioactive waste canisters.
[c] Other wastes include high-activity waste (equipment and soils), contaminated dirt and grout from the Preprocessing Facility high-level mixed radioactive waste, and end-of-life WTP low-activity waste melters, as applicable.
[d] This number includes 6,120 shipments of sulfate grout.

Key: CH=contact-handled; IHLW=immobilized high-level radioactive waste; ILAW=immobilized low-activity waste; N/A=not applicable (no offsite shipments); RH=remote-handled; TRU=transuranic; Vit.=vitrification; WTP=Waste Treatment Plant.

Source: SAIC 2007a, 2008.

Transportation risks were calculated assuming that all shipments would be transported by rail or truck. DOE could decide to use a combination of both truck and rail for transporting materials. Note that the accident and fatality rates are per truck-kilometer or railcar-kilometer, as indicated in Section H.6.2. If DOE decides to ship waste materials using multiple railcars per transport, both accident and fatality rates would increase proportionally. The incident-free population dose would also increase proportionally as the exposure time increases; exposure time would be a function of the rail speed and the length of the waste package in each railcar. Therefore, rail transport per-shipment risk factors would increase proportionally as well. Hence, the risk results presented here are applicable irrespective of future decisions on multiple railcars per transport.

Table H–8 summarizes the risks of transportation under each Tank Closure alternative. These risks were calculated by multiplying the previously given per-shipment factors by the number of shipments over the duration of the program and, for the radiological doses, by the health risk conversion factors. The values presented in Table H–8 show that the total radiological accident risks (the product of the frequency and consequences) are very small under all alternatives. The nonradiological accidents (the potential for fatalities as a direct result of traffic accidents) present the greatest risks. Considering that the transportation activities analyzed under the Tank Closure alternatives would occur from about 20 to over 150 years and the average number of traffic fatalities in the United States is about 40,000 per year (DOT 2007), the traffic fatality risk under all alternatives would be very small.

Table H–8. Tank Closure Alternatives – Risks of Transporting Radioactive Waste

Alt.	Transport	Number of Shipments[a]	Incident-Free				Accident		One-Way Offsite Travel (10^6 km)
			Crew		Population				
			Dose (person-rem)	Risk (LCFs)	Dose (person-rem)	Risk (LCFs)	Rad. Risk (LCFs)	Nonrad. Risk (traffic fatalities)	
2A	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	104,621	259.67	1.56×10^{-1}	72.50	4.4×10^{-2}	1.2×10^{-11}	2.8×10^{-2}	N/A
2B	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	128,171	261.69	1.57×10^{-1}	72.52	4.4×10^{-2}	5.5×10^{-8}	3.4×10^{-2}	N/A
3A	Off site	3,567	624.88	3.75×10^{-1}	189.02	1.13×10^{-1}	8.6×10^{-4}	2.2×10^{-1}	11.0
	On site	68,044	217.29	1.30×10^{-1}	157.93	9.5×10^{-2}	9.1×10^{-7}	1.8×10^{-2}	N/A
3B	Off site	3,567	624.88	3.75×10^{-1}	189.02	1.13×10^{-1}	8.6×10^{-4}	2.2×10^{-1}	11.0
	On site	85,284	464.23	2.79×10^{-1}	76.56	4.6×10^{-2}	9.1×10^{-7}	2.3×10^{-2}	N/A
3C	Off site	3,567	624.88	3.75×10^{-1}	189.02	1.13×10^{-1}	8.6×10^{-4}	2.2×10^{-1}	11.0
	On site	119,994	599.61	3.60×10^{-1}	147.98	8.9×10^{-2}	9.1×10^{-7}	3.3×10^{-2}	N/A
4	Off site	3,599	630.46	3.78×10^{-1}	190.71	1.14×10^{-1}	8.7×10^{-4}	2.2×10^{-1}	11.1
	On site	143,118	455.78	2.73×10^{-1}	115.07	6.9×10^{-2}	1.4×10^{-6}	3.9×10^{-2}	N/A
5	Off site	3,245	568.50	3.41×10^{-1}	171.95	1.03×10^{-1}	7.8×10^{-4}	2.0×10^{-1}	10.0
	On site	50,285	221.71	1.33×10^{-1}	85.11	5.1×10^{-2}	7.7×10^{-7}	1.3×10^{-2}	N/A
6A, Base Case	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	426,899	449.85	2.70×10^{-1}	60.38	3.6×10^{-2}	2.0×10^{-6}	9.6×10^{-2}	N/A
6A, Option Case	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	444,640	497.61	2.99×10^{-1}	73.63	4.4×10^{-2}	2.0×10^{-6}	1.01×10^{-1}	N/A
6B, Base Case	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	360,591	560.35	3.36×10^{-1}	88.93	5.3×10^{-2}	2.0×10^{-6}	1.0×10^{-1}	N/A
6B, Option Case	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	378,288	608.02	3.65×10^{-1}	102.18	6.1×10^{-2}	2.0×10^{-6}	1.05×10^{-1}	N/A
6C	Off site[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	128,171	261.69	1.57×10^{-1}	72.52	4.4×10^{-2}	5.5×10^{-8}	3.4×10^{-2}	N/A

[a] Offsite shipments are based on truck transport of transuranic waste (current practice for transport to Waste Isolation Pilot Plant).
[b] Under this Tank Closure alternative, no transuranic waste would be generated from treatment of tank waste.
Note: To convert kilometers to miles, multiply by 0.6214.
Key: Alt.=Alternative; km=kilometers; LCF=latent cancer fatality; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological.

The risks to various MEIs under incident-free transportation conditions were estimated for the hypothetical exposure scenarios identified in Section H.5.3. The estimated doses to workers, escorts, and the public are presented in Table H–9. Doses are presented on a per-event basis (person-rem per event), as it is unlikely that the same person would be exposed to multiple events; for those that could have multiple exposures, the cumulative dose could be calculated. The maximum dose to a crewmember was based on the same individual driving every shipment for the duration of the campaign. Note that the potential exists for larger individual exposures if multiple exposure events occur. For example, the dose to a person stuck in traffic next to a shipment of RH-TRU waste for 30 minutes was calculated to be 12 millirem. This scenario was considered a one-time event for that individual. The dose to an escort was estimated per trip to WIPP. Note that the maximum annual dose to a transportation worker would be 100 millirem per year unless the individual is a trained radiation worker, which would administratively limit the annual dose to 2 rem (DOE Standard 1098-99). The exposure to each individual escort would be administratively limited to 2 rem per year (DOE Standard 1098-99).

Table H–9. Tank Closure Alternatives – Estimated Dose to Maximally Exposed Individuals During Incident-Free Transportation Conditions

Receptor	Dose to Maximally Exposed Individual
Workers	
Crewmember (truck/rail driver)	2 rem per year[a]
Inspector	2.8×10^{-2} rem per event per hour of inspection
Rail yard worker[b]	8×10^{-3} rem per event
Escort (rail transport)[b]	3×10^{-2} rem per trip
Escort (truck transport)	3.8×10^{-3} rem per trip
First responder (accidents with no release)	2.6×10^{-3} rem per event per one-half hour
Public	
Resident (along the rail route)[b]	6.3×10^{-7} rem per event
Resident (along the truck route)	3.0×10^{-7} rem per event
Person in traffic congestion	1.2×10^{-2} rem per event per one-half-hour stop
Resident near the rail yard during classification[b]	8.3×10^{-5} rem per event
Person at a rest stop/gas station	2.5×10^{-4} rem per event per hour of stop
Gas station attendee	2.6×10^{-4} rem per event

[a] Maximum administrative dose limit per year for a trained radiation worker (truck/rail crewmember).

[b] If the offsite transport were to use rail, with escort.

A member of the public residing along the route would likely receive multiple exposures from passing shipments. The cumulative dose to this resident can be calculated, assuming all shipments passed his or her home. The cumulative doses can be calculated, assuming that the resident would be present for every shipment and would be unshielded at a distance of 30 meters (about 98 feet) from the route. Therefore, the cumulative dose would depend on the number of truck or rail shipments passing a particular point and would be independent of the actual route being considered. The maximum dose to this resident, if all the materials were shipped via this route, would be about 1 millirem. This dose corresponds to that for the truck shipments under Tank Closure Alternative 4, which would have an estimated 3,600 truck shipments of CH- and RH-TRU waste shipments in about 40 years.

The accident risk assessment and the impacts shown in Table H–8 take into account the entire spectrum of potential accidents, from “fender benders” to extremely severe collisions. To provide additional insight into the severity of accidents in terms of the potential dose to an MEI and the public, an accident consequences assessment was performed for a maximum reasonably foreseeable hypothetical transportation accident with a likelihood of occurrence of greater than 1 in 10 million per year. The results, presented in Table H–8, include all accidents, irrespective of their likelihood.

The maximum reasonably foreseeable offsite transportation accident with the highest consequences is an accident involving a truck shipment of RH-TRU waste. This severe-impact, high-temperature fire accident has a likelihood of occurrence of 4.7×10^{-7} per shipment in the rural area. The per-shipment likelihood of such an accident in suburban and urban areas is 9.4×10^{-9} and 2.8×10^{-10}, respectively. The consequences of such an accident in terms of dose and risk of LCFs to an MEI, an individual standing 100 meters (330 feet) downwind from the accident, and the population residing within 80 kilometers (50 miles) in the rural, suburban, and urban zones are provided in Table H–10.

Table H–10. Tank Closure Alternatives – Estimated Dose to the Population and to Maximally Exposed Individuals During the Most Severe Potential Accident

Material and Accident Location		Population[a]		Maximally Exposed Individual[b]	
		Dose (person-rem)	**Risk (LCFs)**	**Dose (rem)**	**Risk (LCFs)**
Remote-handled transuranic waste	Rural	0.382	2.3×10^{-4}	0.027	1.6×10^{-5}
	Suburban	16.2	9.7×10^{-3}	0.027	1.6×10^{-5}
	Urban	110	6.6×10^{-2}	0.027	1.6×10^{-5}

a Population extends at a uniform density to a radius of 80 kilometers (50 miles). The weather condition was assumed to be Pasquill Stability Class D, with a windspeed of 4 meters per second (9 miles per hour).

b The individual is assumed to be 100 meters (330 feet) downwind from the accident and exposed to the entire plume of the radioactive release from a 2-hour, high-temperature fire. The weather condition was assumed to be Pasquill Stability Class F, with a windspeed of 1 meter per second (2.2 miles per hour).

Key: LCF=latent cancer fatality.

H.7.2 FFTF Decommissioning Alternatives

Table H–11 provides the estimated number of shipments for various wastes under all FFTF Decommissioning alternatives. The numbers of shipments were calculated using the estimated volumes and packagings for each waste type given in Appendix D, Section D.2, as well as the waste container and shipment characteristics provided in Table H–2. The values presented for offsite shipments in Table H–11 are the estimated numbers of truck shipments for the Idaho options of treating sodium metals and RH-SCs at INL. If these options are selected, the treated sodium, in the form of 50 weight-percent caustic solution, would be transported back to Hanford, and the treated RH-SCs would be shipped to NTS or transported back to Hanford for disposal.

Table H–11. FFTF Decommissioning Alternatives – Estimates of Number of Shipments

Alternative	Number of Shipments							
	Offsite Shipments[a]			Onsite Shipments				
	Sodium Metal	**Caustic Solution**	**RH-SCs**	**Sodium Metal**	**Caustic Solution**	**RH-SCs**	**Reactor Vessel**	**Other Wastes[b]**
1	0	0	0	0	0	0	0	NA
2	78	191	9	13	191	5	0	6,310
3	78	191	9	13	191	5	1	6,329

a These are estimates for truck transports. Rail transports would be one-half of the values given.

b Other wastes include components and decommissioning waste transported to an Integrated Disposal Facility and sanitary and hazardous landfills.

Key: NA=not analyzed; RH-SC=remote-handled special component.

Source: SAIC 2007b.

FFTF Decommissioning alternatives consist of three distinct activities: facility disposition, disposition of bulk sodium, and disposition of RH-SCs. Table H–12 summarizes the risks of transportation under each disposition activity. The risks were calculated by multiplying the previously given per-shipment factors by the number of shipments over the duration of the program and, for the radiological doses, by the health risk conversion factors. The values presented in Table H–12 show that the total radiological accident risks (the product of the frequency and consequences) are very small under all disposition activities. In contrast, the nonradiological accidents (the potential for fatalities as a direct result of traffic accidents) present the greatest risks.

Table H–12. FFTF Decommissioning Alternatives – Risks of Transporting Radioactive Waste

Disposition Activity	Location (transport mode)	Number of Shipments	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk (LCFs)	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk (LCFs)	Accident: Rad. Risk (LCFs)	Accident: Nonrad. Risk (traffic fatalities)	One-Way Offsite Travel (10^5 km)
Disposition of bulk sodium	INL (T)	269	3.52	2.1×10^{-3}	0.945	5.7×10^{-4}	4.15×10^{-8}	5.2×10^{-3}	2.60
	INL (R)	135	0.157	9.4×10^{-5}	0.171	1.0×10^{-4}	3.54×10^{-8}	2.2×10^{-2}	1.43
	Hanford	204	0.115	6.9×10^{-5}	0.0112	6.7×10^{-6}	4.19×10^{-12}	8.4×10^{-5}	N/A
Disposition of RH-SCs	INL (T)[a]	9	0.839	5.0×10^{-4}	0.330	2.0×10^{-4}	4.48×10^{-8}	1.9×10^{-4}	0.096
	INL (R)[a]	5	0.170	1.0×10^{-4}	0.074	4.4×10^{-5}	4.47×10^{-8}	3.5×10^{-4}	0.060
	Hanford[a]	5	0.032	1.9×10^{-5}	0.0048	2.9×10^{-6}	1.26×10^{-10}	2.86×10^{-6}	N/A
Facility disposition	Hanford (Alt. 2)	6,310	(b)	(b)	(b)	(b)	(b)	4.17×10^{-3}	N/A
	Hanford (Alt. 3)	6,330	0.033	2×10^{-5}	0.0025	1.5×10^{-6}	7.6×10^{-11}	4.18×10^{-3}	N/A

[a] This transport includes one shipment of caustics generated from treatment of sodium metal within the remote-handled special components.

[b] Not analyzed because all waste is sanitary or hazardous (not radioactive).

Note: To convert kilometers to miles, multiply by 0.6214.

Key: Alt.=Alternative; Hanford=Hanford Site; INL=Idaho National Laboratory; km=kilometers; LCF=latent cancer fatality; N/A=not applicable; Nonrad.=nonradiological; R=rail; Rad.=radiological; RH-SC=remote-handled special component; T=truck.

The risks to various MEIs under incident-free transportation conditions were estimated for the hypothetical exposure scenarios identified in Section H.5.3. The estimated doses to workers, escorts, and the public are presented in Table H–13. Doses are presented on a per-event basis (person-rem per event), as it is unlikely that the same person would be exposed to multiple events; for those that could have multiple exposures, the cumulative dose could be calculated. The maximum dose to a crewmember was based on the same individual driving every shipment for the duration of the campaign. Note that the potential exists for larger individual exposures if multiple exposure events occur. For example, the dose to a person stuck in traffic next to a shipment of RH-SCs for 30 minutes was calculated to be 19 millirem. This scenario was considered a one-time event for that individual. The dose to an escort was estimated per trip (either to NTS or INL). Note that the maximum annual dose to a transportation worker would be 100 millirem per year unless the individual is a trained radiation worker, which would administratively limit the annual dose to 2 rem (DOE Standard 1098-99). The exposure to each individual escort (considered a trained radiation worker) would be administratively limited to 2 rem per year.

Table H–13. FFTF Decommissioning Alternatives – Estimated Dose to Maximally Exposed Individuals During Incident-Free Transportation Conditions

Receptor	Dose to Maximally Exposed Individual
Workers	
Crewmember (truck/rail driver)	2 rem per year[a]
Inspector	4.6×10^{-2} rem per event per hour of inspection
Rail yard worker	7×10^{-4} rem per event
Escort (rail transport)	1.7×10^{-2} rem per trip (Nevada Test Site)
Escort (truck transport)	2.0×10^{-3} rem per trip (Nevada Test Site)
First responder (accidents with no release)[b]	2.6×10^{-3} rem per event per one-half hour
Public	
Resident (along the rail route)	1.2×10^{-6} rem per event
Resident (along the truck route)	5.8×10^{-7} rem per event
Person in traffic congestion	1.9×10^{-2} rem per event per one-half hour stop
Resident near the rail yard during classification	6.4×10^{-6} rem per event
Person at a rest stop/gas station	5.3×10^{-3} rem per event per hour of stop
Gas station attendee	4.9×10^{-4} rem per event

a Maximum administrative dose limit per year for a trained radiation worker (truck/rail crewmember).

b This dose would result from use of Type B casks for remote-handled special component transport. The external dose was assumed to be similar to that for the immobilized high-level radioactive waste rail cask.

Key: FFTF=Fast Flux Test Facility.

A member of the public residing along the route would likely receive multiple exposures from passing shipments. The cumulative dose to this resident can be calculated, assuming all shipments passed his or her home. The cumulative dose can be calculated, assuming that the resident would be present for every shipment and would be unshielded at a distance of 30 meters (about 98 feet) from the route. Therefore, the cumulative dose would depend on the number of truck or rail shipments passing a particular point and would be independent of the actual route being considered. The maximum dose to this resident, if all the materials are shipped via this route, would be less than 0.2 millirem. This dose corresponds to that for the rail shipments under both alternatives if the Idaho options of treating sodium and RH-SCs at INL are selected, which would require an estimated number of about 140 rail shipments over 2 years.

The accident risk assessment and the impacts shown in Table H–12 account for the entire spectrum of potential accidents, from “fender benders” to extremely severe collisions, regardless of their likelihood. To provide additional insight into the severity of accidents in terms of the potential dose to an MEI and the public, an accident consequence assessment was performed for a maximum reasonably foreseeable hypothetical transportation accident with a likelihood of occurrence of greater than 1 in 10 million per year.

The maximum reasonably foreseeable offsite transportation accident with the highest consequences is an accident involving a truck shipment of sodium metal, which would be a severe-impact, high-temperature fire accident. This accident has a likelihood of occurrence of 1.3×10^{-6} per shipment in the rural area. The per-shipment likelihood of such an accident in suburban and urban areas is 2.5×10^{-7} and 2.8×10^{-8}, respectively. The consequences of such an accident in terms of dose and risk of LCFs to an MEI, an individual standing 100 meters (330 feet) downwind from the accident, and the population residing within 80 kilometers (50 miles) of the accident in rural, suburban, and urban zones are provided in Table H–14.

Table H–14. FFTF Decommissioning Alternatives – Estimated Dose to the Population and to Maximally Exposed Individuals During the Most Severe Potential Accident

Material and Accident Location		Population[a]		Maximally Exposed Individual[b]	
		Dose (person-rem)	Risk (LCFs)	Dose (rem)	Risk (LCFs)
Sodium metal	Rural	0.22	1.3×10^{-4}	0.0015	9.0×10^{-7}
	Suburban	1.20	7.2×10^{-4}	0.0015	9.0×10^{-7}
	Urban	5.60	3.4×10^{-3}	0.0015	9.0×10^{-7}

[a] Population extends at a uniform density to a radius of 80 kilometers (50 miles). The weather condition was assumed to be Pasquill Stability Class D, with a windspeed of 4 meters per second (9 miles per hour).

[b] The individual was assumed to be located 100 meters (300 feet) downwind from the accident and to be exposed to the entire plume of the radioactive release from a 2-hour, high-temperature fire. The weather condition was assumed to be Pasquill Stability Class F, with a windspeed of 1 meter per second (2.2 miles per hour).

Key: FFTF=Fast Flux Test Facility; LCF=latent cancer fatality.

H.7.3 Waste Management Alternatives

Table H–15 provides the estimated number of shipments for various wastes under all Waste Management alternatives. The shipment numbers were calculated using the estimated waste volumes for each waste type given in Appendix D, Section D.3, and the waste container and shipment characteristics provided in Table H–2. The values presented for the offsite waste shipments in Table H–15 were estimated for truck transports. Rail transports were assumed to be one-half of the values given.

Table H–15. Waste Management Alternatives – Estimates of Number of Shipments

Alternative	Number of Shipments			
	Offsite Shipments[a]		Onsite Shipments	
	LLW[b]	MLLW[b]	LLW[b]	MLLW[b]
1	0	0	807	196
2	15,273	1,318	807	196
3	15,273	1,318	807	196

[a] These are estimates for truck transports. Rail transports would be one-half of the values given.

[b] These include both contact- and remote-handled wastes.

Key: LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste.

Source: SAIC 2007c.

Table H–16 shows the risks of transportation under each of the Waste Management alternatives. The risks were calculated by multiplying the previously given per-shipment factors by the number of shipments over the duration of the program and, for radiological doses, by the health risk conversion factors. The values presented in Table H–12 show that the total radiological accident risks (the product of the frequency and consequences) are very small under all alternatives. In contrast, the nonradiological accidents (the potential for fatalities as a direct result of traffic accidents) present the greatest risks.

Table H–16. Waste Management Alternatives – Risks of Transporting Radioactive Waste

Alt.	Transport (Mode)	Number of Shipments	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk (LCFs)	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk (LCFs)	Accident: Rad. Risk (LCFs)	Accident: Nonrad. Risk (traffic fatalities)	One-Way Offsite Travel (10^6 km)
1	Off site	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	On site	1,003	2.62	1.6×10^{-3}	0.0826	5×10^{-5}	2.10×10^{-9}	2.6×10^{-4}	N/A
2	Off site (T)	16,591	2,617	1.57	351.8	2.11×10^{-1}	6.0×10^{-5}	1.10	53.8
	Off site (R)	8,289	52.69	3.16×10^{-2}	134.57	8.1×10^{-2}	2.9×10^{-5}	4.28	27.4
	On site	1,003	4.3	2.6×10^{-3}	0.138	8×10^{-5}	3.6×10^{-9}	4.1×10^{-4}	N/A
3	Off site (T)	16,591	2,617	1.57	351.8	2.11×10^{-1}	6.0×10^{-5}	1.10	53.8
	Off site (R)	8,289	52.69	3.2×10^{-2}	134.57	8.1×10^{-2}	2.9×10^{-5}	4.28	27.4
	On site	1,003	2.62	1.6×10^{-3}	0.0826	5×10^{-5}	2.10×10^{-9}	2.6×10^{-4}	N/A

Note: To convert kilometers to miles, multiply by 0.6214.
Key: Alt.=Alternative; km=kilometers; LCF=latent cancer fatality; N/A=not applicable (no offsite waste would be accepted at the Hanford Site); Nonrad.=nonradiological; R=rail; Rad.=radiological; T=truck.

The risks to various MEIs under incident-free transportation conditions were estimated for the hypothetical exposure scenarios identified in Section H.5.3. The estimated doses to workers, escorts, and the public are presented in Table H–17 on a per-event basis (person-rem per event), as it is unlikely that the same person would be exposed to multiple events; for those that could have multiple exposures, the cumulative dose could be calculated. The maximum dose to a crewmember is based on the same individual driving every shipment for the duration of the campaign. Note that the potential exists for larger individual exposures if multiple exposure events occur. For example, the dose to a person stuck in traffic next to a shipment of RH-waste in a Type B cask for 30 minutes was calculated to be 10 millirem. Note that the maximum annual dose to a transportation worker would be 100 millirem per year unless the individual is a trained radiation worker, which would administratively limit the annual dose to 2 rem (DOE Standard 1098-99).

Table H–17. Waste Management Alternatives – Estimated Dose to Maximally Exposed Individuals During Incident-Free Transportation Conditions

Receptor	Dose to Maximally Exposed Individual
Workers	
Crewmember (truck/rail driver)	2 rem per year[a]
Inspector	2.3×10^{-2} rem per event per hour of inspection
Rail yard worker	8×10^{-3} rem per event
First responder (accidents with no release)[b]	1.2×10^{-3} rem per event per one-half hour
Public	
Resident (along the rail route)	6.3×10^{-7} rem per event
Resident (along the truck route)	3.0×10^{-7} rem per event
Person in traffic congestion	1.0×10^{-2} rem per event per one-half hour stop
Resident near the rail yard during classification	8.3×10^{-5} rem per event
Person at a rest stop/gas station	9.7×10^{-5} rem per event per hour of stop
Gas station attendee	7.9×10^{-4} rem per event

[a] Maximum administrative dose limit per year for a trained radiation worker (truck/rail crewmember).
[b] This dose results from using a Type B cask for remote-handled waste.

A member of the public residing along the route would likely receive multiple exposures from passing shipments. The cumulative dose to this resident can be calculated assuming all shipments passed his or her home. The cumulative doses can be calculated assuming that the resident would be present for every shipment and would be unshielded at a distance of 30 meters (about 98 feet) from the route. Therefore, the cumulative dose would depend on the number of truck or rail shipments passing a particular point and would be independent of the actual route being considered. The maximum dose to this resident, if all the materials are shipped via this route, would be less than 5 millirem. This dose corresponds to those for truck shipments under Waste Management Alternatives 2 and 3, which have an estimated number of truck shipments of about 16,600 over 20 years.

The accident risk assessment and the impacts shown in Table H–16 account for the entire spectrum of potential accidents, from "fender benders" to extremely severe collisions. To provide additional insight into the severity of accidents in terms of the potential dose to an MEI and the public, an accident consequence assessment was performed for a maximum reasonably foreseeable hypothetical transportation accident with a likelihood of occurrence of greater than 1 in 10 million per year. The results, presented in Table H–18, include all accidents, irrespective of their likelihood.

Table H–18. Waste Management Alternatives – Estimated Dose to the Population and the Maximally Exposed Individuals During the Most Severe Potential Accident

Material and Accident Location		Population[a]		Maximally Exposed Individual[b]	
		Dose (person-rem)	Risk (LCFs)	Dose (rem)	Risk (LCFs)
Idaho National Laboratory RH-LLW	Rural	1.62	9.7×10^{-4}	0.00031	1.9×10^{-7}
	Suburban	25.24	1.5×10^{-2}	0.00031	1.9×10^{-7}
	Urban	120.88	7.3×10^{-2}	0.00031	1.9×10^{-7}

a Population extends at a uniform density to a radius of 80 kilometers (50 miles). The weather condition was assumed to be Pasquill Stability Class D, with a windspeed of 4 meters per second (9 miles per hour).

b The individual is assumed to be 100 meters (300 feet) downwind from the accident and to be exposed to the entire plume of the radioactive release from a 2-hour, high-temperature fire. The weather condition was assumed to be Pasquill Stability Class F, with a windspeed of 1 meter per second (2.2 miles per hour).

Key: LCF=latent cancer fatality; RH-LLW=remote-handled low-level radioactive waste.

The maximum reasonably foreseeable offsite transportation accident with the highest consequences is an accident involving a rail shipment of RH-LLW, which would be a severe-impact, high-temperature fire accident with a likelihood of occurrence of 2.5×10^{-7} per shipment in the rural area. The per-shipment likelihood of such an accident in suburban and urban areas is 2.8×10^{-8} and 5.3×10^{-9}, respectively. The consequences of such an accident in terms of dose and risk of LCFs to an MEI, an individual standing 100 meters (330 feet) downwind from the accident, and the population residing within 80 kilometers (50 miles) in the rural, suburban, and urban zones are provided in Table H–18.

H.8 IMPACT OF CONSTRUCTION AND OPERATIONAL MATERIAL TRANSPORT

This section evaluates the impacts of transporting the materials required to construct new facilities, as well as those required to immobilize, vitrify, or solidify the liquid waste and transport it to storage or burial locations. The construction materials considered are concrete, cement, sand/gravel/dirt, asphalt, steel, and piping. The materials required for waste solidification and transport include glass formers, fly ash, blast furnace slag, canisters, cylinders, and boxes. The impacts were evaluated based on the number of truck shipments required for each of the materials and the distances from their points of origin to Hanford. The origins of these materials are defined as on site, local, and regional, with an average distance of 8, 72, and 256 kilometers (5, 45, and 160 miles) each way, respectively. The truck kilometers for all material shipments under each alternative were calculated by summing the distances for all activities from construction through deactivation and closure (if applicable) under each alternative. The truck accident and fatality rates were assumed to be those provided earlier for onsite radioactive waste transport. Table H–19 summarizes the impacts in terms of the total number of kilometers, accidents, and fatalities for all alternatives. The results in Table H–19 indicate that for the Tank Closure alternatives, the potential for traffic fatalities is the largest under Alternative 6A, Option Case, with the potential for six traffic fatalities, followed by Alternative 3C and Alternative 6A, Base Case, each potentially resulting in approximately three traffic fatalities. Considering that the duration of Alternative 6A is more than 150 years, the estimated annual fatality is very small.

Table H–19. Estimated Impacts of Construction and Operational Material Transport

Alternative	Total Distance Traveled (million kilometers)	Number of Accidents	Number of Fatalities
Tank Closure Alternatives			
1	1.04	0.13	0.009
2A	49.47	6.08	0.41
2B	64.97	7.99	0.54
3A	67.17	7.52	0.51
3B	94.33	11.60	0.78
3C	407.19	50.08	3.38
4	120.24	14.79	1.00
5	87.96	10.82	0.73
6A, Base Case	385.42	47.41	3.20
6A, Option Case	767.02	94.34	6.37
6B, Base Case	140.35	17.26	1.16
6B, Option Case	272.83	33.56	2.26
6C	71.12	8.75	0.59
FFTF Decommissioning Alternatives			
1: No Action	0.031	0.0038	0.0003
2: Entombment			
Facility Disposition	1.83	0.225	0.015
Options at Hanford[a]	0.35	0.043	0.0029
Disposition of Bulk Sodium	0.039	0.005	0.0003
Disposition of RH-SCs	0.31	0.039	0.0026
Options at INL[a]	0.18	0.022	0.0015
Disposition of Bulk Sodium	0.018	0.002	0.0001
Disposition of RH-SCs	0.16	0.020	0.0013
3: Removal			
Facility Disposition	2.06	0.254	0.017
Options at Hanford[a]	0.35	0.043	0.0029
Options at INL[a]	0.18	0.022	0.0015
Waste Management Alternatives			
1: No Action	0.40	0.05	0.003
2: Disposal in IDF, 200-East Area Only	4.15	0.51	0.03
Disposal Group 1	8.40	1.03	0.07
Disposal Group 2	29.72	3.66	0.25
Disposal Group 3	37.98	4.67	0.32
3: Disposal in IDF, 200-East and 200-West Areas	4.15	0.51	0.03
Disposal Group 1	7.65	0.94	0.06
Disposal Group 2	29.89	3.68	0.25
Disposal Group 3	38.08	4.68	0.32

[a] These are common activities under both Alternatives 2 and 3.

Note: To convert kilometers to miles, multiply by 0.6214. The baseline includes activities related to facility disposition; the options include treatment of bulk sodium and RH-SCs.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; INL=Idaho National Laboratory; RH-SC=remote-handled special component.

H.9 CONCLUSIONS

Transportation of any commodity involves a risk to both transportation crewmembers and members of the public. This risk results directly from transportation-related accidents and indirectly from the increased levels of pollution from vehicle emissions, regardless of the cargo. The transportation of certain materials, such as hazardous or radioactive waste, can pose an additional risk due to the unique nature of the material itself.

H.9.1 Tank Closure Alternatives

Tank closure activities would generate various radioactive waste materials that would require transport for disposition to offsite locations such as New Mexico (WIPP) under Alternatives 3 through 5 as well as to onsite locations within Hanford. In addition, all alternatives would require transport of various nonradioactive materials for construction and operational support. Based on the results presented in the previous sections, the following conclusions were reached (see Tables H–7, H–8, and H–19):

- It is unlikely that transportation of radioactive waste would cause an additional fatality as a result of radiation from either incident-free operations or postulated transportation accidents.
- The highest risk to the public would be under Alternative 4, in which about 3,600 truck shipments of TRU waste would be transported to WIPP and 143,118 shipments of various radioactive waste materials would be transported to onsite waste burial and storage locations.
- The lowest risk to the public would be under Alternative 2A, in which only 104,621 shipments of various radioactive wastes would be transported to onsite waste burial and storage locations over a period of 75 years.
- Alternatives 3 through 5 and 6 have risk estimates between those of Alternatives 2A and 4.
- The nonradiological accidents (the potential for fatalities as a direct result of traffic accidents) present the greatest risks. Considering that the transportation activities analyzed would occur over about 20 to 150 years and the average number of traffic fatalities in the United States is about 40,000 per year, the traffic fatality risks under all alternatives are very small.

H.9.2 FFTF Decommissioning Alternatives

FFTF decommissioning activities would generate various radioactive materials that would require transport to both offsite and onsite locations for treatment and/or disposal. Radioactive materials would need to be transported off site if DOE decides to treat sodium or RH-SCs at INL. Based on the results presented in the previous section, the following conclusions were reached (see Tables H–11, H–12, and H–19):

- It is unlikely that transportation of radioactive waste would cause an additional fatality due to radiation resulting from either incident-free operations or postulated transportation accidents.
- The highest risk to the public would be under the Idaho options for treatment of bulk sodium and RH-SCs at INL. Alternative 3 adds additional risks for transport of radioactive materials for disposal at an Integrated Disposal Facility and transport of nonradioactive materials for disposal at a sanitary and hazardous landfill.

- The lowest risk to the public would be under the Hanford options for treatment of bulk sodium and RH-SCs at Hanford. Alternative 2 adds some risks for the transport of the nonradioactive materials for disposal at a sanitary and hazardous landfill.

H.9.3 Waste Management Alternatives

The various wastes generated at Hanford from tank closure and FFTF decommissioning activities, along with the waste transported from offsite DOE sources, would be managed and disposed of at an Integrated Disposal Facility. Offsite waste would be accepted at Hanford only under Alternatives 2 and 3. The onsite-generated LLW and MLLW, excluding waste from tank closure and FFTF decommissioning activities, would be common to all alternatives. Transport and disposition of all other waste considered under the Waste Management alternatives were already evaluated under the Tank Closure and FFTF Decommissioning alternatives. Based on the results presented earlier, the following conclusions were reached (see Tables H–15, H–16, and H–19):

- It is unlikely that transportation of radioactive waste would cause an additional fatality as a result of radiation from either incident-free operations or postulated transportation accidents. Note that the maximum annual dose to a transportation worker would be 100 millirem per year unless the individual is a trained radiation worker, which would administratively limit the annual dose to 2 rem **(**DOE Standard 1098-99). Exposure to a maximum annual dose of 2 rem per year would lead to an LCF risk of 0.0012. Assuming that an individual is exposed to the same annual exposure for 20 years, the cumulative LCF risk would be 0.024.

- The highest risk to the public would occur under Alternative 2 or 3, in which about 16,600 shipments of waste would be transported to Hanford from various DOE facilities.

- The lowest risk to the public would occur under Alternative 1, in which no shipments of waste would be transported to Hanford from various DOE facilities.

H.10 LONG-TERM IMPACTS OF TRANSPORTATION

The cumulative impacts of the transportation of radioactive material, consisting of the impacts of historic shipments of radioactive waste and SNF, reasonably foreseeable actions that include transportation of radioactive material, and general radioactive material transportation that is unrelated to a particular action, are detailed in Appendix T. The collective dose to the general population and workers was the measure used to quantify the cumulative transportation impacts. This measure of impact was chosen because it may be directly related to the LCFs using a cancer risk coefficient. Table H–20 summarizes the total worker and general population collective doses from various transportation activities. The table shows that the impacts of this program are quite small compared with the overall transportation impacts. The total collective worker dose from all types of shipments (historical or related to the alternatives, reasonably foreseeable actions, and general transportation) was estimated to range from 406,390 to 407,350 person-rem (about 244 LCFs) for the period from 1943 through 2073 (131 years). The total general population collective dose was estimated to range from 378,680 to 378,940 person-rem (about 227 LCFs). The majority of the collective doses to workers and the general population would be due to the general transportation of radioactive material and shipments of various SNF and reactor fuel materials under the activities related to the Global Nuclear Energy Partnership (see Appendix T, Table T–4). Examples of general transportation activities include shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial LLW to commercial disposal facilities. The total number of LCFs estimated to result from radioactive material transportation over the period from 1943 through 2073 is about 470. Over this same period (131 years), approximately 72.4 million people would die from cancer, based on 554,000 cancer fatalities per year (CDC 2007). The transportation-related

LCFs would be about 0.0007 percent of the annual number of cancer deaths; therefore, any increase would be indistinguishable from the natural fluctuation in the total annual death rate from cancer.

Table H–20. Cumulative Transportation-Related Radiological Collective Doses and Latent Cancer Fatalities

Category	Worker Dose (person-rem)	General Population Dose (person-rem)
Tank Closure alternatives	260–1,224[a]	73–337[b]
FFTF Decommissioning alternatives	0.95–4.4[a]	0.34–1.3[b]
Waste Management alternatives	2,620–2,621[a]	352[b]
Transportation impacts in this *TC & WM EIS*	2,881–3,849[a]	425–690[b]
Other Nuclear Material Shipments (Appendix T)		
Historical	292	317
Reasonably foreseeable	29,214	39,936
General transportation (1943–2073)	374,000	338,000
Total—other nuclear materials (up to 2073)[c]	403,510	378,250
Total Collective Dose (up to 2073)[c]	**406,390–407,350**	**378,680–378,940**
Total Latent Cancer Fatalities	**~244**	**~227**

[a] Range of values among the alternatives for the worker dose.
[b] Range of values among the alternatives for the population dose.
[c] The sum values were rounded to the nearest 10.

Key: FFTF=Fast Flux Test Facility; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.*

Source: Appendix T of this *TC & WM EIS*.

H.11 UNCERTAINTY AND CONSERVATISM IN ESTIMATED IMPACTS

The sequence of analyses performed to generate the estimates of radiological risk for transportation includes (1) determination of the inventory and characteristics, (2) estimation of shipment requirements, (3) determination of route characteristics, (4) calculation of radiation doses to exposed individuals (including estimation of environmental transport and uptake of radionuclides), and (5) estimation of health effects. Uncertainties are associated with each of these steps. Uncertainties exist in the way that the physical systems being analyzed are represented by the computational models; in the data required to exercise the models (due to measurement errors, sampling errors, natural variability, or unknowns caused simply by the future nature of the actions being analyzed); and in the calculations themselves (e.g., approximate algorithms used by the computers).

In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result; however, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, risk analysis is designed to ensure, through uniform and judicious selection of scenarios, models, and input parameters, that relative comparisons of risk among the various alternatives are meaningful. In the transportation risk assessment, this design was accomplished by uniformly applying common input parameters and assumptions to each alternative. Therefore, although considerable uncertainty is inherent in the absolute magnitude of the transportation risk for each alternative, much less uncertainty is associated with the relative differences among the alternatives in a given measure of risk.

In the following sections, areas of uncertainty are discussed for the assessment steps enumerated above. Special emphasis is placed on identifying whether the uncertainties affect relative or absolute measures of risk. The reality and conservatism of the assumptions also are addressed. Where practical, the parameters that most significantly affect the risk assessment results are identified.

H.11.1 Uncertainties in Material Inventory and Characterization

Waste inventories and their physical and radiological characteristics are important input parameters to the transportation risk assessment. The potential number of shipments for all alternatives was primarily based on the projected dimensions of package contents, the strength of the radiation field, the heat that must be dissipated, and assumptions concerning shipment capacities. The physical and radiological characteristics are important in determining the material released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

Uncertainties in the inventory and characterization are reflected in the transportation risk results. If the inventory is overestimated or underestimated, the resulting transportation risk estimates would also be overestimated or underestimated by roughly the same factor. However, the same inventory estimates were used to analyze the transportation impacts of each of the *TC & WM EIS* alternatives. Therefore, for comparative purposes, the observed differences in transportation risks among the alternatives, as given in Table H–8, H–12, and H–16, are believed to represent unbiased, reasonably accurate estimates based on current information in terms of relative risk comparisons.

H.11.2 Uncertainties in Containers, Shipment Capacities, and Number of Shipments

Transportation activities required under each alternative were estimated based in part on assumptions concerning the packaging characteristics and shipment capacities for commercial trucks. Waste shipments would be made in federally and state-certified packages. If a waste type would require a special packaging for offsite transport, the analysis assumed that a specially designed package would be built and certified before the transportation could occur. Shipment capacities have been defined for assessment purposes based on probable future shipment capacities. In reality, the actual shipment capacities may differ from the predicted capacities such that the projected number of shipments and, consequently, the total transportation risk, would change. However, although the predicted transportation risks would increase or decrease accordingly, the relative differences in risks among the alternatives would remain about the same.

H.11.3 Uncertainties in Route Determination

Routes were determined between all origin and destination sites considered in this *TC & WM EIS*. These routes are consistent with current guidelines, regulations, and practices, but may not be the actual routes that would be used in the future. In reality, the actual routes could differ from the analyzed ones with regard to distances and total populations along the routes. Moreover, because materials could be transported over an extended period starting at some time in the future, the highway infrastructures and demographics along the routes could change. These effects were not accounted for in the transportation assessment; however, potential changes are not expected to significantly affect the relative comparisons of risk among the alternatives considered in this *TC & WM EIS*.

H.11.4 Uncertainties in the Calculation of Radiation Doses

The models used to calculate radiation doses from transportation activities introduce further uncertainty into the risk assessment process. Estimating the accuracy or absolute uncertainty of the risk assessment results is generally difficult. The accuracy of the calculated results is closely related to the limitations of the computational models and the uncertainties in each of the input parameters that the model requires. The single greatest limitation facing users of RADTRAN, or any computer code of this type, is the scarcity of data for certain input parameters. Populations (off-link and on-link) along the routes, shipment surface dose rates, and individuals residing near the roads are the most uncertain data in dose calculations. In preparing these data, one makes assumptions that the off-link population is uniformly distributed; the on-link population is proportional to the traffic density, with an assumed occupancy of two persons per car; the shipment surface dose rate is the maximum allowed dose rate; and the potential exists for an individual to be residing at the edge of the road. It is clear that not all of these assumptions are accurate. For example, the off-link population is mostly heterogeneous, and the on-link traffic density varies widely from road to road within a geographic zone (i.e., urban, suburban, or rural). Finally, added to this complexity are assumptions regarding the expected distances between the public and a shipment at a traffic stop, rest stop, or traffic jam and the afforded shielding.

The uncertainties associated with the computational models were reduced by using state-of-the-art computer codes that have undergone extensive review. Because many uncertainties are recognized but difficult to quantify, assumptions were made at each step of the risk assessment process that were intended to produce conservative results (i.e., to overestimate the calculated dose and radiological risk). Because the parameters and assumptions were applied consistently to all of the alternatives, this model bias is not expected to affect the meaningfulness of the relative comparisons of risk; however, the results may not represent the risks in an absolute sense.

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