APPENDIX K
EVALUATION OF HUMAN HEALTH EFFECTS FROM TRANSPORTATION

APPENDIX K
EVALUATION OF HUMAN HEALTH EFFECTS FROM TRANSPORTATION

K.1 Introduction

Transportation of any commodity involves a risk to 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. 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. To permit a complete appraisal of the environmental impacts of the alternatives considered in this Site-Wide Environmental Impact Statement (SWEIS), the human health risks associated with the transportation of radioactive materials are assessed in this appendix.

This appendix provides an overview of the approach used to assess the human health risks that could result from transportation. The topics in this appendix include the scope of the assessment, packaging and determination of potential transportation routes, analytical methods used for the risk assessment (such as computer models), and important assessment assumptions. In addition, to aid in the understanding and interpretation of the results, specific areas of uncertainty are described with an emphasis on how the uncertainties could affect comparisons of the alternatives.

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

K.2 Scope of Assessment

The scope of the transportation human health risk assessment, including the alternatives and options, transportation activities, potential radiological and nonradiological impacts, and transportation modes considered, is described in this section. There are several shipping arrangements for various radioactive materials that cover all alternatives evaluated. This evaluation focuses on using onsite and offsite public highway systems. Additional details of the assessment are provided in the remaining sections of this appendix.

K.2.1 Transportation-related Activities

The transportation risk assessment is limited to estimating the human health risks related to transportation for each alternative. The risks to workers or to the public during loading, unloading, and handling prior to or after shipment are not included in the transportation assessment. The transportation risk assessment does not address possible impacts of increased transportation levels on local traffic flow, noise levels, or infrastructure. The risks from these activities are considered as part of the facility operation impacts.

K.2.2 Radiological Impacts

For each alternative, radiological risks (those risks that result from the radioactive nature of the materials) are assessed for both incident-free (normal) and accident transportation 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 people.

All radiological impacts are calculated in terms of committed dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (see Title 10 of the *Code of Federal Regulations* [CFR], Part 20), which is 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 (DOE) Office of NEPA (National Environmental Policy Act) Policy and Compliance, based on Interagency Steering Committee on Radiation Safety guidance (DOE 2003a).

K.2.3 Nonradiological Impacts

In addition to the radiological risks posed by transportation activities, vehicle-related risks are also assessed for nonradiological causes (causes related to the transport vehicles only; not their radioactive cargo) for the same transportation routes. The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for accident conditions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that directly result in fatalities unrelated to the shipment of cargo.

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

K.2.4 Transportation Modes

All shipments are assumed to take place by dedicated truck.

K.2.5 Receptors

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

K.3 Packaging and Transportation Regulations

K.3.1 Packaging Regulations

The primary regulatory approach to promote safety from radiological exposure is the specification of standards for the packaging of radioactive materials. Packaging represents the primary barrier between the radioactive material being transported and radiation exposure to the public, workers, and the 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 or spent nuclear fuel, packagings must contain and shield their contents in the event of severe accident conditions. The type of packaging used is determined by the total radioactive hazard presented by the material within the packaging. Four basic types of packaging are used: Excepted, Industrial, Type A, and Type B.

Excepted packagings are limited to transporting materials with extremely low levels of radioactivity. Industrial packagings 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 packagings are designed to protect and retain their contents under normal transport conditions and must maintain sufficient shielding to limit radiation exposure to handling personnel. Type A packaging, typically a 55-gallon (208-liter) drum or standard waste box, is commonly used to transport radioactive materials with higher concentrations or amounts of radioactivity than Excepted, or Industrial packagings. Type B packagings are used to transport material with the highest radioactivity levels, and are designed to protect and retain their contents under transportation accident conditions. They are described in more detail in the following sections. Packaging requirements are an important consideration for transportation risk assessment. Appendix F of the 1999 *Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico,* (*1999 SWEIS)* (DOE 1999a) provides a listing and characteristics of the packagings assumed to be used for this SWEIS.

Radioactive materials shipped in Type A containers, or packagings, are subject to specific radioactivity limits, identified as A1 and A2 values in 49 CFR 173.435 ("Table of A1 and A2 Values for Radionuclides"). In addition, external radiation limits, as prescribed in 49 CFR 173.441 ("Radiation Level Limitations"), must be met. If the A1 or A2 limits are exceeded, the material must be shipped in a Type B container unless it can be demonstrated that the material meets the definition of "low specific activity." If the material qualifies as low specific activity as defined in 10 CFR Part 71 ("Packaging and Transportation of Radioactive Material") and 49 CFR Part 173 (Shippers—General Requirements for Shipments and Packagings), it may be shipped in an approved low-specific-activity shipping container. 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:

- Operating temperatures ranging from -40 degrees Celsius (°C) (-40 degrees Fahrenheit [°F]) to 70 °C (158 °F);
- External pressures ranging from 0.25 to 1.4 kilograms per square centimeter (3.5 to 20 pounds per square inch);
- 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; and
- Impact of a 6-kilogram (13-pound) steel cylinder with rounded ends dropped from 1 meter (40 inches) onto the most vulnerable surface.

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

- Free drop from 9 meters (30 feet) onto an unyielding surface in a position most likely to cause damage;
- Free drop from 1 meter (3.3 feet) onto the end of a 15-centimeter (6-inch) diameter vertical steel bar;
- Exposure to temperatures of 800 °C (1,475 °F) for at least 30 minutes;
- For all packages, immersion in at least 15 meters (50 feet) of water;
- For fissile material packages, immersion in at least 0.9 meters (3 feet) of water in an orientation most likely to result in leakage; and
- For spent nuclear fuel packages, immersion in at least 200 meters (660 feet) of water for 1 hour.

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

K.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 could occur as a result of concentrating too much fissile material in one place); and
- Provide physical protection against theft and sabotage during transit.

The U.S. Department of Transportation (DOT) regulates the transportation of hazardous materials in 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 vehicle and driver requirements. DOT also regulates the labeling, classification, and marking of radioactive material packagings.

The U.S. Nuclear Regulatory Commission (NRC) regulates the packaging and transporting 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 packagings.

DOE, through its management directives, Orders, and contractual agreements, ensures the protection of public health and safety by imposing on its transportation activities standards equivalent to those of DOT and NRC. According to 49 CFR 173.7(d), packagings made by or under the direction of DOE may be used for transporting Class 7 materials (radioactive materials) when the packages are evaluated, approved, and certified by DOE against packaging standards equivalent to those specified in 10 CFR Part 71 ("Packaging and Transportation of Radioactive Material").

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

The Federal Emergency Management Agency 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. The Federal Emergency Management Agency, an agency of the Department of Homeland Security, coordinates Federal and state participation in developing emergency response plans and is responsible for the development of the interim Federal Radiological Emergency Response Plan. This plan is designed to coordinate Federal support to state and local governments, upon request, during the event of a transportation incident involving radioactive materials.

K.4 Transportation Analysis Impact Methodology

The transportation risk assessment is based on the alternatives described in Chapter 3 of the SWEIS. **Figure K–1** summarizes the transportation risk assessment methodology. After the SWEIS alternatives were identified and the requirements of the shipping campaign were understood, data were collected on material characteristics and accident parameters.

Transportation impacts calculated in this SWEIS are presented in two parts: impacts of incident-free or routine transportation and impacts of transportation accidents. Impacts of incident-free transportation and transportation accidents were further divided into nonradiological and radiological impacts. Nonradiological impacts could result from transportation accidents in terms of traffic fatalities. Radiological impacts of incident-free transportation include impacts on members of the public and crew from radiation emanating from materials in the shipment. Radiological impacts from accident conditions consider all foreseeable scenarios that could damage transportation packages leading to releases of radioactive materials to the environment.

The impact of transportation accidents is expressed in terms of probabilistic risk, which is the probability of an accident multiplied by the consequences of that accident and summed over all reasonably conceivable 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 of accidents and consequences were evaluated using a method developed by NRC and published in the *Final Environmental Impact Statement on the Transportation of Radioactive Materials by Air and Other Modes*, NUREG-0170 (NRC 1977); *Shipping Container Response to Severe Highway and Railway Accident Conditions*, NUREG/CR-4829 (NRC 1987); and, *Reexamination of Spent Fuel Shipping Risk Estimates*, NUREG/CR-6672 (NRC 2000). Hereafter, these reports are cited as: *Radioactive Material Study*, NUREG-0170; *Modal Study*, NUREG/CR-4829; and *Reexamination Study*, NUREG/CR-6672. Radiological accident risk is expressed in terms of additional LCFs, and nonradiological accident risk is expressed in terms of additional immediate (traffic) fatalities. Incident-free risk is also expressed in terms of additional LCFs.

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck crewmembers involved in the actual transportation. The general public includes 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 Transportation Routing Analysis Geographic Information System (TRAGIS) computer program (Johnson and Michelhaugh 2003) was used to choose representative routes and the 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 computer code (Neuhauser and Kanipe 2003), which calculates incident and accident risks on a per-shipment basis. The risks under each alternative are determined by summing the products of per-shipment risks for each waste type by its number of shipments.

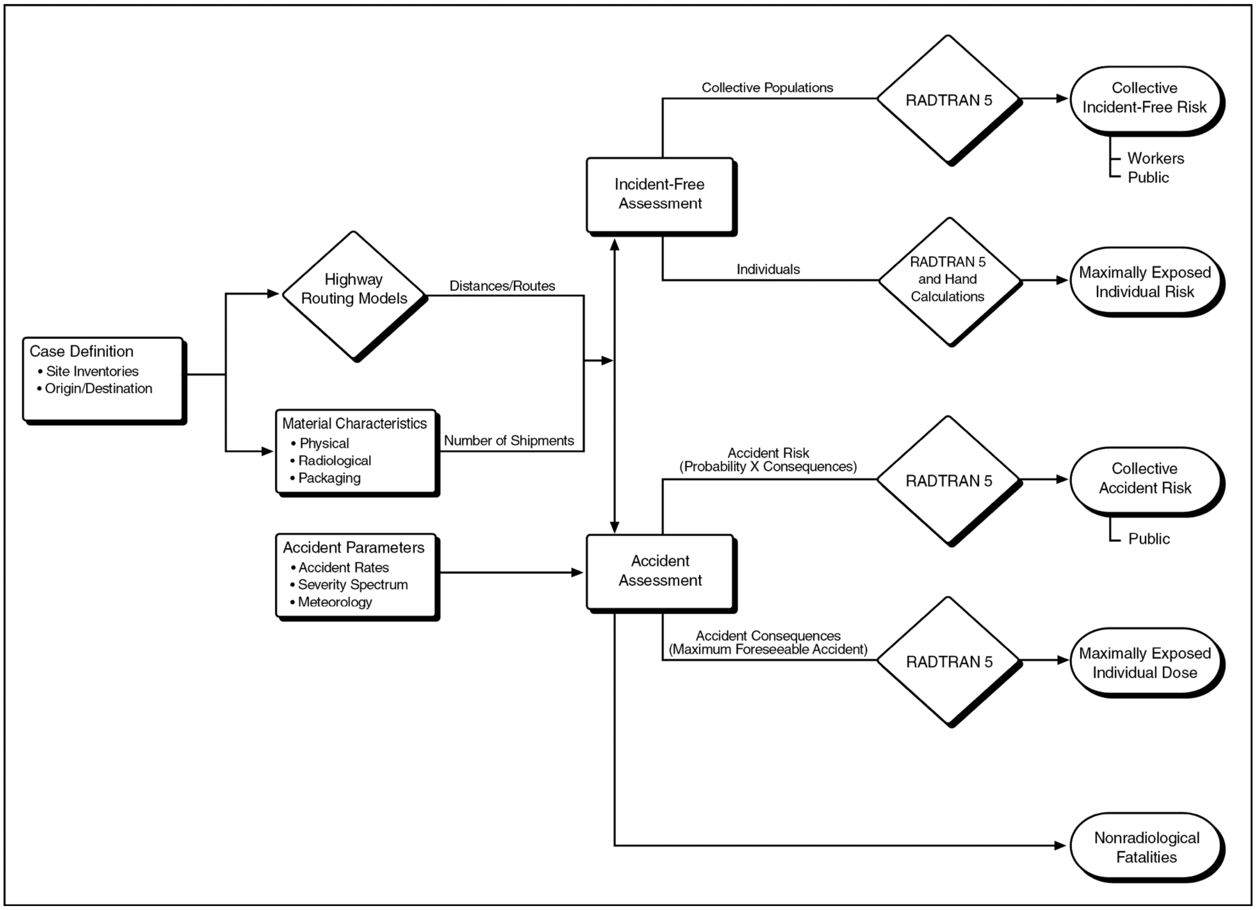

Figure K–1 Transportation Risk Assessment

The RADTRAN 5 computer code (Neuhauser and Kanipe 2003) is used for 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 the 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 the 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 is used as the primary means of comparing the various alternatives.

The RISKIND computer code (Yuan et al. 1995) is used to estimate the doses to MEIs and populations for the worst-case 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 a 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 using RADTRAN 5. Whereas the collective risk results provide a measure of the overall risks of 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?"

K.4.1 Transportation Routes

The types of radioactive and nonradioactive materials that would be expected to require offsite transport include special nuclear material, low-level radioactive waste, transuranic waste, irradiated target material, industrial waste, and hazardous waste. These materials would be transported to, from, and on the Los Alamos National Laboratory (LANL) site during routine operations. Offsite shipments, both to and from LANL, are carried by commercial carriers (including truck, air freight, and Government trucks) and by DOE safe secure transport trailers. Air freight transportation is performed for special packages with limited quantities. The amount and form of materials that would be transported using air freight are similar to those evaluated in the *1999 SWEIS* (DOE 1999a) with similar impacts, and therefore are not reevaluated.

For offsite transport, highway routes were determined using the routing computer program TRAGIS (Johnson and Michelhaugh 2003). 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, which were developed from the U.S. Geological Survey digital line graphs and the U.S. Bureau of the Census Topological Integrated Geographic Encoding and Referencing System. The population densities along each route are derived from 2000 Census Bureau data (Johnson and Michelhaugh 2003). The features in TRAGIS allow users to determine routes for shipment of radioactive materials that conform to DOT regulations as specified in 49 CFR Part 397.

Offsite Route Characteristics

Route characteristics that are important to the radiological risk assessment include the total shipment distance and population distribution along the route. The specific route selected determines both the total potentially exposed population and the expected frequency of transportation-related accidents. Route characteristics are expressed in terms of travel distances and population densities in rural, suburban, and urban areas according to the following breakdown:

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

To assess incident-free and transportation accident impacts, route characteristics were determined for offsite shipments from the LANL site to the:

- Pantex Site in Amarillo, Texas;
- Lawrence Livermore National Laboratory, California;
- Y-12 Complex, and Oak Ridge National Laboratory in Oak Ridge, Tennessee;
- Savannah River Site in Aiken, South Carolina;
- Nevada Test Site in Mercury, Nevada;
- EnergySolutions site in Clive, Utah as a representative of a commercial disposal site;
- East Tennessee Waste Treatment Center in Oak Ridge, Tennessee; and
- Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.

These sites would constitute the locations where the majority of shipments would be transported. **Table K–1** summarizes the route characteristics for these sites.

Table K–1 Offsite Transport Truck Route Characteristics

Origin	*Destination*	*Nominal Distance (kilometers)*	*Distance Traveled in Zones (kilometers)*			*Population Density in Zone (number per square kilometer)*			*Number of Affected Persons* [a]
			Rural	*Suburban*	*Urban*	*Rural*	*Suburban*	*Urban*	
Truck Routes									
LANL	Pantex	668	617	42	9	4.2	451.2	2135.1	63,989
	SRS	2,680	1,987	617	76	11.9	314.8	2,240.1	622,377
	NTS	1,250	1,069	141	40	7.6	338.2	2,626.2	256,117
	Commercial [b]	1,076	938	112	26	6.9	386.2	2,464.3	183,804
	ETWT	2,248	1,759	438	51	10.8	300.4	2,243.2	425,534
	LLNL	1,822	1,632	168	22	8.0	312.6	2,369.9	189,378
	Y-12	2,372	1,848	465	59	11.0	300.8	2,271.4	471,946
	WIPP	605	568	35	2	5.9	251.1	1,891.5	25,541
Truck Routes (local from I-25 to LANL)									
LANL to Pojoaque		31	27	3.8	0.2	5.8	362.6	2,408.5	3,227
Pojoaque to Santa Fe [c]		52	44	8	0	18.9	178.4	0	3,563

SRS = Savannah River Site, NTS = Nevada Test Site, ETWT = East Tennessee Waste Treatment Center (at K-25 site in Oak Ridge, Tennessee), LLNL= Lawrence Livermore National Laboratory, Y-12 = Y-12 Complex at Oak Ridge, WIPP = Waste Isolation Pilot Plant.

[a] The estimated number of persons residing within 0.5 miles (800 meters) along the transportation route.

[b] The EnergySolutions site in Clive, Utah, is a representative commercial disposal facility.

[c] Pass through Santa Fe bypass (New Mexico 599) to Interstate 25.

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

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

Analyzed truck routes for shipments of radioactive waste materials are shown in **Figure K–2**.

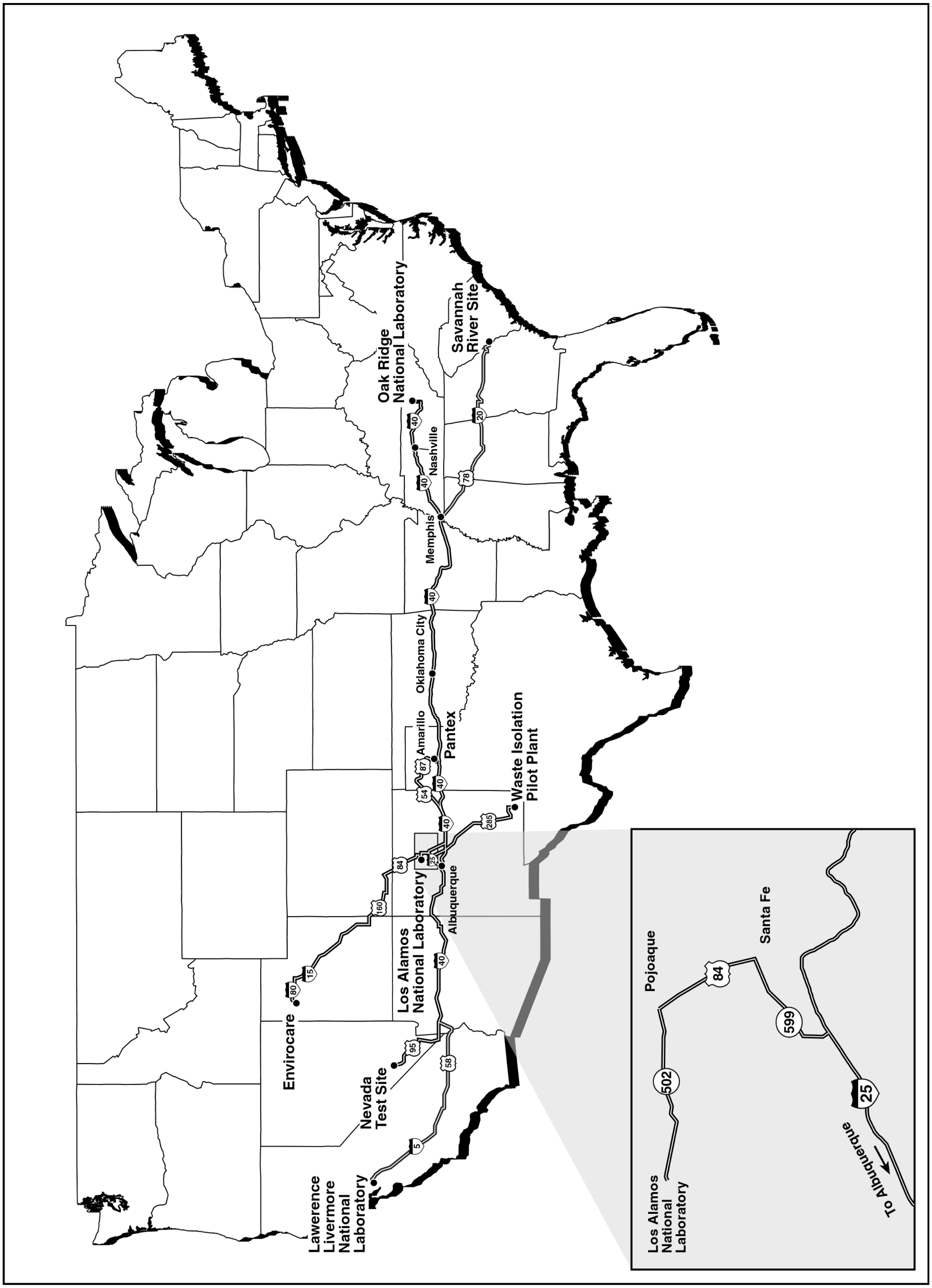

Figure K–2 Analyzed Truck Routes

K.4.2 Radioactive Material Shipments

Transportation of all radioactive material (waste and special nuclear material) types is assumed to be in certified or certified-equivalent packaging on exclusive-use vehicles. Legal-weight heavy-haul combination trucks are used for highway transportation. Type A packages are transported on common flatbed or covered trailers; Type B packages are generally shipped on trailers designed specifically for the packaging being used. For transportation by truck, the maximum payload weight is considered to be about 48,000 pounds (about 22,000 kilograms), based on the Federal gross vehicle weight limit of 80,000 pounds (36,288 kilograms). However, there are large numbers of multitrailer combinations (known as longer combination vehicles) with gross weights in excess of the Federal limit in operation on rural roads and turnpikes in some states (DOT 2003), but for evaluation purposes, the load limit for the legal truck was based on the Federal gross vehicle weight.

Several types of packagings (containers, or casks) would be used to transport the radioactive materials. The various wastes that would be transported under the alternatives in this SWEIS include demolition and construction debris and hazardous waste, low-level radioactive waste, transuranic waste, and mixed low-level radioactive waste. **Table K–2** lists the types of containers used, along with their volumes and the number of containers in a shipment. A shipment is defined as the amount of materials transported on a single truck.

Table K–2 Radioactive Material Type and Container Characteristics

Material Type	*Container*	*Container Volume (cubic meters)* [a]	*Container Mass (kilograms)* [b]	*Number of Containers per Shipment*
Special Nuclear Material	9975, 6M, and FL containers	0.13 and 0.32	113-168	1 to 40 per safe and secure trailer truck
Class A low-level radioactive waste	208-liter drum	0.21	272	80 per truck
Low-level radioactive waste and mixed low-level radioactive waste	B-25 Box	2.55	4,536	5 per truck
Low-level radioactive waste (remote-handled) [c]	208-liter drum	0.21	272	10 per truck cask
Low specific activity waste	Soft liner	7.31	10,886	2 per truck
Transuranic waste (remote-handled)	208-liter drum	0.21	272	3 per truck cask; 1 cask per truck
Transuranic waste (contact-handled)	208-liter drum	0.21	272	14 per TRUPACT II; 3 TRUPACT IIs per truck [d]
Construction and demolition debris	Roll on/Roll off	15.30	Not applicable	1 per truck
Hazardous	208-liter drum	0.21	272	60 to 80 per truck [e]

[a] Container exterior volume. To convert cubic meters to cubic feet, multiply by 35.315; liters to gallons, multiply by 0.26417.
[b] Nominal filled container mass. Container mass includes the mass of the container shell, its internal packaging, and the materials within. To convert kilograms to pounds, multiply by 2.2046.
[c] Remote-handled low-level radioactive wastes are packaged in 55-gallons (208-liter) drums and transported in Type B shipping casks.
[d] Nominal number per truck. Depending on the waste density 2 or 3 TRUPACT IIs are shipped per truck. About 30 percent of transuranic wastes are considered to have high density leading to 2 TRUPACT II per truck shipments (LANL 2006).
[e] Depending on the waste density, 60 to 80 drums could be shipped per truck.
Note: Construction debris and hazardous wastes would be shipped to local offsite locations.

The number of shipping containers per shipment was estimated on the basis of the dimensions and weights of the shipping containers; the Transport Index, which is the maximum dose rate at 1 meter (3.3 feet) from a container;[1] limits on special nuclear material mass per shipment; and the transport vehicle dimensions and weight limits. In general, the various wastes were assumed to be transported on standard truck semi-trailers in a single stack.

Special nuclear material is transported on DOE safe and secure transport trailers. Special nuclear material transports include uranium-233, plutonium pits, plutonium oxides and enriched uranium that are used in support of nuclear criticality safety, nuclear weapons, and the production of mixed oxide fuel, or to effect disposition. These materials are transported between LANL, Pantex, Lawrence Livermore National Laboratory, Savannah River Site, Nevada Test Site, Y-12 Complex, and Oak Ridge National Laboratory.

For the purposes of analysis, it was assumed that all low-level radioactive waste would be disposed of at LANL, a DOE site (the Nevada Test Site, in Nevada), or a commercial site (EnergySolutions, in Utah) depending on waste classification. The commercial site only accepts the low-level and mixed low-level radioactive waste known as Class A waste per 10 CFR 61.55, and provided that the waste can be contact-handled. The DOE site accepts all classes of low-level and mixed low-level radioactive waste. Mixed low-level radioactive waste could also be transported to a facility (such as East Tennessee Waste Treatment Center) for treatment and temporary storage, but eventually would have to be transported to an acceptable waste disposal site. The generated transuranic waste would be disposed of at WIPP.

K.5 Incident-Free Transportation Risks

K.5.1 Radiological Risk

During incident-free transportation of radioactive materials, 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, their 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 crewmembers are the drivers of the shipment vehicle. The general population is composed of the persons residing within 0.5 miles (800 meters) of the truck routes (off-link), persons sharing the road (on-link), and persons at stops. Exposures to workers who would load and unload the shipments are not included in this analysis, but are included in the occupational estimates for plant workers. Exposures to the inspectors are evaluated and presented separately.

Collective doses for the crew and general population were calculated by 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 the radioactive material has a defined regulatory limit of 10 millirem per hour at 2 meters (6.6 feet) from the cask (10 CFR 71.47 and 49 CFR 173.441). If a waste container shows a high external dose rate that could exceed the DOT limit of 10 millirem per hour 2 meters from the outer, or

[1] *Based on the Transport Index definition provided in 10 CFR 71.43 and 49 CFR 173.410.*

lateral, edge of the vehicle, it would be transported in a Type A or Type B shielded shipping cask or container.

Waste container dose rate, or its Transport Index, depends on distribution and quantities of radionuclides, waste density, shielding provided by the packaging, and self-shielding provided by the waste mixture. The most important gamma emitting radionuclides in the waste are cobalt-60 and cesium-137. The MicroShield computer program (Grove 2003) was used to estimate the external dose rates for the various waste containers based on unit concentrations of cobalt-60 and cesium-137. Dose rate calculations were performed assuming both shielded and bare containers. For the shielded option, waste containers were assumed to be in appropriate Type A or Type B shipping casks. For example, remote-handled transuranic wastes were assumed to be shipped in CNS 10-160B or RH-72B casks (both are Type B casks), and remote-handled low-level radioactive waste in a CNS 10-160B cask or a CNS 14-195 (a Type A shielded cask).

Waste and nuclear materials that are expected to be transported both on site and off site are usually of low dose rate, on the order of one millirem per hour at 1 meter (3.3 feet). However, exhumation of wastes from material disposal areas (MDAs) would be expected to result in multiple waste types having various levels of radioactive inventory and dose rates. Using an enveloping waste composition for each waste type, a conservative dose rate for its container was calculated. These dose rates were compared with those used in other DOE NEPA documentations, and an appropriate conservative value was assigned to each waste type. The remote-handled and contact-handled transuranic waste package dose rates at 1 meter (3.3 feet) were assigned at 10 millirem per hour and 4 millirem per hour, respectively (DOE 1997). Dose rates for low-level radioactive waste and mixed low-level radioactive waste were assigned at 1 millirem per hour at 1 meter (3.3 feet). Dose rate for low specific activity waste was assigned at 0.10 millirem per hour at 1 meter (3.3 feet). Dose rate for the remote handled low-level radioactive wastes in Type A or Type B casks were assigned at 1 millirem per hour at 1 meter (3.3 feet). Dose rates for the special nuclear material shipments of uranium-233, plutonium, and enriched uranium are assigned at 10, 5 and 1 millirem per hour at 1 meter (3.3 feet), respectively.

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. The unit risk factors were combined with routing information, such as the shipment distances in various population density zones, to determine the risk for a single shipment (a shipment risk factor) between a given origin and destination. Unit risk factors were developed on the basis of travel on interstate highways and freeways, as required by 49 CFR Parts 171 to 177 for highway-route-controlled quantities of radioactive material within rural, suburban, and urban population zones, by using RADTRAN 5 and its default data. In addition, it was 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. Note that the size of the waste package and assumptions regarding public shielding afforded by the general housing structure within each zone would be major contributing factors in the calculated dose.

The radiological risks from transporting radioactive materials 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 public and workers (DOE 2003a).

K.5.2 Nonradiological Risk

The nonradiological risks, or vehicle-related health risks, resulting from incident-free transport that may be associated with the generation of air pollutants by transport vehicles during shipment are independent of the radioactive nature of the shipment. Historically, 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 et al. 1982). The unit risk factors account for the potential fatalities from emissions of particulates and sulfur dioxide, but they are applicable only to the urban population zone. The emission unit risk factor for truck transport in the urban area is estimated to be 5.0×10^{-8} fatalities per kilometer; for rail transport, it is 2.0×10^{-7} fatalities per kilometer (DOE 2002a). These risk factors were only used for estimating emission risk while the transport is in the urban area. The emergence of considerable data regarding threshold values for various chemical constituents of vehicle exhaust has made linear extrapolation to estimate the risks from truck or rail emissions untenable. This calculation has been eliminated from RADTRAN in its recent revision (Neuhauser and Kanipe 2003). Therefore, no risk factors have been assigned to the vehicle emissions in this SWEIS.

K.5.3 Maximally Exposed Individual Exposure Scenarios

The maximum individual doses for routine offsite transportation were estimated for transportation workers and for members of the general population. Three hypothetical scenarios were evaluated to determine the MEI in the general population. These scenarios are (DOE 2002a):

- A person caught in traffic and located 4 feet (1.2 meters) from the surface of the shipping container for 30 minutes;
- A resident living 98 feet (30 meters) from the highway used to transport the shipping container; and
- A service station worker at a distance of 52 feet (16 meters) 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 is 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, or accumulate an exposure of 2 rem per year. The maximum exposure rate for a member of a truck crew as a nonradiation worker is 2 millirem per hour (10 CFR 71.47).

K.6 Transportation Accident Risks and Maximum Reasonably Foreseeable Consequences

K.6.1 Methodology

The offsite transportation accident analysis considers the impact of accidents during the transportation of waste. 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 an accident analysis methodology developed by NRC. This section provides an overview of the methodologies; detailed descriptions of various methodologies are found in the *Radioactive Material Transportation Study,* NUREG-0170, *Modal Study,* NUREG/CR-4829, and *Reexamination Study,* NUREG/CR-6672 (NRC 1977, 1987, 2000). Accidents that could potentially breach the shipping container are represented by a spectrum of accident severities and radioactive release conditions. Historically, most transportation accidents involving radioactive materials have resulted in little or no release of radioactive material from the shipping container. Consequently, the analysis of accident risks takes into account a spectrum of accidents ranging from high-probability accidents of low severity to hypothetical high-severity accidents that have a correspondingly low probability of occurrence. The accident analysis calculates the probabilities and consequences from this spectrum of accidents.

To provide DOE and the public with a reasonable assessment of radioactive waste transportation accident impacts, two types of analysis were performed. First an accident risk assessment was performed that takes into account the probabilities and consequences of a spectrum of potential accident severities using a methodology developed by the NRC (NRC 1977, 1987, 2000). For the spectrum of accidents considered in the analysis, accident consequences in terms of collective "dose risk" to the population within 50 miles (80 kilometers) were determined using the RADTRAN 5 computer program (Neuhauser et al. 2000). 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. Second, to represent the maximum reasonably foreseeable impacts to individuals and populations should an accident occur, maximum radiological consequences were calculated in an urban or a suburban population zone for an accidental release with a likelihood of occurrence greater than 1-in-10 million per year using the RISKIND computer program (Yuan et al. 1995).

K.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 for Surface Freight Transportation: A Reexamination,* ANL/ESD/TM-150 (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 accident involvement count as the numerator of the fraction and vehicular activity (total travel distance in truck kilometers) as the denominator. Accident rates were 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 commercial truck transportation, the rates presented 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 are computed for each state based on statistics compiled by the Federal Highway Administration, Office of Motor Carriers, from 1994 to 1996. A fatality caused by an accident is the death of a member of the public who is killed instantly or dies within 30 days due to the 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 were the "mean" accident and fatality rates given in ANL/ESD/TM-150 (Saricks and Tompkins 1999) under interstate, primary, and total categories for rural, suburban, and urban population zones, respectively. The accident rates were 3.15, 3.52, and 3.66 per 10 million truck kilometers, and the fatality rates were 0.88, 1.49, and 2.32 per 100 million truck kilometers for rural, suburban, and urban zones, respectively.

For DOE safe secure trailer truck transport, the DOE operational experience between 1984 and 1999 was used. The mean probability of an accident requiring towing of a disabled trailer truck was about 6 per 100 million kilometers (DOE 2000). The number of safe and secure trailer accidents is too small to support allocating this overall rate among the various types of routes (interstate, primary, others) used in the accident analysis. Therefore, data for the relative rate of accidents on these route types, or influence factor, provided in *Determination of Influence Factor and Accident Rates for Armored Tractor/Safe Secure Trailer* (Phillips, Clauss, and Blower 1994), were used to estimate accident frequencies for rural, urban, and suburban transports. Accident fatalities for the safe secure trailer transports were estimated using the commercial truck transport fatality per accident ratios within each zone.

For local and regional transport, New Mexico State accident and fatality rates were used. The data were provided in ANL/ESD/TM-150 (Saricks and Tompkins 1999). The rates used were 1.13 accidents per 10 million truck kilometers and 1.18 fatalities per 100 million truck kilometers.

K.6.3 Accident Severity Categories and Conditional Probabilities

Accident severity categories for potential radioactive waste transportation accidents are described in the *Radioactive Material Transportation Study* (NRC 1977) for radioactive waste in general and in the *Modal Study* (NRC 1987) and the *Reexamination Study* (NRC 2000) for spent nuclear fuel. The methods described in the *Modal Study* and the *Reexamination Study* are applicable to transportation of radioactive materials in a Type B spent fuel cask. The accident severity categories presented in the *Radioactive Material Transportation Study* would be applicable to all other waste transported offsite.

The *Radioactive Material Transportation Study* (NRC 1977) originally was used to estimate conditional probabilities associated with accidents involving transportation of radioactive materials. The *Modal Study* and the *Reexamination Study* (NRC 1987, 2000) are initiatives taken by NRC to refine more precisely the analysis presented in *Radioactive Material Transportation Study* for spent nuclear fuel shipping casks.

Whereas the *Radioactive Material Transportation Study* (NRC 1977) analysis was primarily performed using best engineering judgments and presumptions concerning cask response, the later studies rely on sophisticated structural and thermal engineering analysis and a probabilistic assessment of the conditions that could be experienced in severe transportation accidents. The latter results are based on representative spent nuclear fuel casks assumed to have been designed, manufactured, operated, and maintained according to national codes and standards. Design parameters of the representative casks were chosen to meet the minimum test criteria specified in 10 CFR Part 71. The study is believed to provide realistic, yet conservative, results for radiological releases under transport accident conditions.

In the *Modal Study* and the *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 the potential impacts of 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 are, therefore, 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 occurrence of that accident, an approach consistent with the methodology used by RADTRAN 5 computer code. The RADTRAN 5 code sums the product of consequences and probability over all accident categories to obtain a probability-weighted risk value referred to in this appendix as "dose risk," which is expressed in units of person-rem.

K.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 and G) and unstable (Pasquill Stability Classes A and B) conditions occur 33.5 percent and 8 percent of the time, respectively (DOE 2002a). The neutral weather conditions predominate in each season, but most frequently in the 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 likelihood of occurrence greater than 1 in 10 million per year) were assessed under both stable (Class F with a windspeed of 1 meter per second [2.2 miles per hour]) and neutral (Class D with a windspeed of 4 meters per second [8.8 miles per hour]) atmospheric conditions. These calculations provide an estimate of the potential dose to an individual and a population within a zone, respectively. The individual dose would represent the MEI in an accident under worst-case weather conditions (stable condition, with minimum diffusion and dilution). The population dose would represent an accident under average weather conditions.

K.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 the radioactivity in the container that could be released to the atmosphere in a given severity of accident. Release fractions vary according to material type and the physical or chemical properties of the radioisotopes. Most solid radionuclides are nonvolatile and are, therefore, relatively nondispersible.

Representative release fractions were developed for each waste and container type on the basis of DOE and NRC reports (DOE 1994, 2002b, 2003a; NRC 1977, 2000). The severity categories and corresponding release fractions provided in the NRC documents cover a range of accidents from no impact (zero speed) to impacts with speed in excess of 120 miles (193 kilometers) per hour onto an unyielding surface. Traffic accidents that could occur at the LANL site would be of minor impact due to lower local speed, with no release potential.

For radioactive materials transported in a Type B cask, the particulate release fractions were developed consistent with the models in the *Reexamination Study* (NRC 2000) and adapted in the *West Valley Demonstration Project Waste Management Environmental Impact Statement* (DOE 2003b). For materials transported in Type A containers (such as 55-gallon [208-liter] drums, boxes, and soft liners), the fractions of radioactive material released from the shipping container were based on recommended values from *Radioactive Material Transportation Study* and *DOE Handbook on Airborne Release and Respirable Fractions* (NRC 1977, DOE 1994). For contact-handled and remote-handed transuranic waste, the release fractions corresponding to the *Radioactive Material Transportation Study* severity categories (NRC 1977) and adapted in the *WIPP Supplemental Environmental Impact Statement* were used (DOE 1997, 2002b).

K.6.6 Acts of Sabotage or Terrorism

In the aftermath of the tragic events of September 11, 2001, DOE is continuing to assess 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 attacks 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 special nuclear materials such as plutonium and enriched uranium. These materials would be transported using DOE's safe and secure transport equipment escorted by protective force personnel. DOE has a proven record of protecting these assets; no diversion of any DOE nuclear material has occurred. The details of any postulated terrorist attack, as well as DOE's plans for the security of its facilities and terrorist countermeasures are classified. A classified appendix has been prepared for this SWEIS that includes impact analyses for intentional acts of destruction related to transportation.

Additionally, DOE has evaluated the impacts of acts of sabotage and terrorism on transportation of spent nuclear fuel and high-level radioactive waste shipments (DOE 1996, 2002a). The spectrum of events considered ranges from direct attack on the shipping cask from afar to hijacking and exploding the 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 is dependent on the nature of the attack (type of explosive or weapon used). The sabotage event evaluated 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 EIS)* was considered as an enveloping analysis for most transportation activities in this LANL SWEIS. The event was assumed to involve either a truck-sized, or a rail-sized cask containing light water reactor spent nuclear fuel. The consequences of such an act were calculated to result in an MEI dose (at 140 meters [460 feet]) of 40 to 110 rems for events involving a rail-sized or truck-sized cask, respectively. These events would lead to an increase in risk of fatal cancer to the MEI by 2 to 7 percent (DOE 2002a). The quantity of radioactive materials transported under all LANL SWEIS alternatives and the associated transuranic radionuclide source term would be less than that considered in this analysis. Therefore, estimates of risk in the *Yucca Mountain EIS* envelope the risks from an act of sabotage or terrorism involving the radioactive waste transported under all alternatives in this LANL SWEIS.

K.7 Risk Analysis Results

Per-shipment risk factors have been calculated for the collective populations of exposed persons and for 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. Radiological risk factors per-shipment for incident-free transportation and accident conditions for the offsite disposal locations are presented in **Table K–3**. **Table K–4** presents the radiological risk factors per-shipments for travel on two route segments between LANL and Santa Fe. This analysis was performed to be consistent with those evaluated in the *1999 SWEIS* (DOE 1999a).

Table K–3 Risk Factors per Truck Shipment of Radioactive Material

Waste Materials	Transport Origin or Destination	Incident-Free				Accident	
		Crew Dose (person-rem)	Crew Risk (LCF)	Population Dose (person rem)	Population Risk (LCF)	Radiological Risk (LCF)	Non-radiological Risk (traffic fatalities)
LLW (B) [a]	Nevada Test Site	0.0124	7.46×10^{-6}	0.00392	2.35×10^{-6}	1.67×10^{-8}	0.0000249
LLW (D) [b]		0.0149	8.97×10^{-6}	0.00664	3.99×10^{-6}	2.18×10^{-8}	0.0000249
High activity [c]		0.0124	7.46×10^{-6}	0.00392	2.35×10^{-6}	1.67×10^{-8}	0.0000249
LLW (RH) [d]		0.0108	6.49×10^{-6}	0.00203	1.22×10^{-6}	3.28×10^{-13}	0.0000249
DD&D bulk [e]		0.00137	8.21×10^{-7}	0.000274	1.64×10^{-7}	1.80×10^{-10}	0.0000249
LSA		0.00137	8.21×10^{-7}	0.000274	1.64×10^{-7}	1.30×10^{-8}	0.0000249
LSA	Commercial [f]	0.00118	7.06×10^{-7}	0.000234	1.40×10^{-7}	9.63×10^{-9}	0.0000211
DD&D bulk [e]		0.00118	7.06×10^{-7}	0.000234	1.40×10^{-7}	1.34×10^{-10}	0.0000211
LLW (B) [a]		0.0107	6.41×10^{-6}	0.00334	2.01×10^{-6}	1.41×10^{-8}	0.0000211
LLW (D) [b]		0.0129	7.71×10^{-6}	0.00567	3.40×10^{-6}	1.84×10^{-8}	0.0000211
CH-TRU	WIPP	0.0228	0.0000137	0.00725	4.35×10^{-6}	3.30×10^{-11}	0.0000143
RH-TRU		0.0346	0.0000208	0.00919	5.51×10^{-6}	7.66×10^{-13}	0.0000143
SNM	Pantex	0.00637	3.82×10^{-6}	0.00726	4.36×10^{-6}	9.23×10^{-11}	1.73×10^{-6}
SNM	LLNL	0.00349	2.09×10^{-6}	0.00396	2.37×10^{-6}	3.56×10^{-10}	4.83×10^{-6}
SNM	Y-12	0.00459	2.75×10^{-6}	0.00529	3.18×10^{-6}	1.01×10^{-15}	6.94×10^{-6}
SNM	SRS	0.0260	1.56×10^{-5}	0.0302	1.81×10^{-5}	8.89×10^{-10}	8.08×10^{-6}
SNM	NTS	0.00240	1.44×10^{-6}	0.00281	1.68×10^{-6}	2.76×10^{-10}	3.50×10^{-6}
PuO_2 [g]	SRS	0.00785	4.71×10^{-6}	0.00804	4.82×10^{-6}	4.35×10^{-8}	8.08×10^{-6}
PuO_2 [h]	SRS	0.0393	0.0000236	0.0270	0.0000162	9.25×10^{-8}	8.08×10^{-6}
U-233 [i, j]	ORNL	0.0516	0.000031	0.0705	0.000042	1.25×10^{-9}	6.94×10^{-6}
U-233 [i]	NTS	0.0435	0.000026	0.0371	0.000022	4.91×10^{-10}	3.50×10^{-6}
U-233R [k]	WIPP	0.0346	0.0000208	0.00919	5.51×10^{-6}	1.61×10^{-11}	0.0000143

LCF = latent cancer fatality, LLW = low-level radioactive waste, RH = remote-handled, DD&D = decontamination, decommissioning, and demolition, LSA = low specific activity waste, CH = contact-handled, TRU = transuranic waste, WIPP = Waste Isolation Pilot Plant, LLNL = Lawrence Livermore National Laboratory, NTS = Nevada Test Site, Y-12 = Y-12 Complex in Oak Ridge, SNM = special nuclear material, PuO_2 = plutonium dioxide, SRS = Savannah River Site, U-233 = uranium-233.

[a] Low-level radioactive waste transported in Type A B-25 boxes.
[b] Low-level radioactive waste transported in 55-gallon (208-liter) drums.
[c] High activity low-level radioactive waste containing more than 10 nanocuries per gram of transuranic waste transported in Type A, B-25 boxes. This waste is comparable to Class B or Class C of 10 CFR Part 61 waste classification.
[d] Remote-handled low-level radioactive waste transported in 55-gallon (208-liter) drums.
[e] Decommissioning and demolition bulk managed waste, with a radioactive inventory of equivalent 0.0001 curies of plutonium-239 per cubic yard.
[f] Commercial site is in Utah.
[g] Polished plutonium oxide (very low decay impurities).
[h] Unpolished plutonium oxide (high concentration of decay impurities).
[i] Uranium-233 oxide and metal suitable for the support of criticality experiment programs with very low uranium-232 impurities.
[j] Uranium-233 oxide that is currently at LANL and is considered surplus material to be shipped to ORNL for processing for disposal.
[k] Uranium-233 oxide residue that is contaminated with plutonium and to be disposed as RH-TRU waste at WIPP.

Table K–4 Risk Factors per Truck-Shipment of Radioactive Material at Nearby Routes

Waste Materials	Transport Route Segment	Incident-Free				Accident	
		Crew Dose (person-rem)	Crew Risk (LCF)	Population Dose (person rem)	Population Risk (LCF)	Radiological Risk (LCF)	Non-radiological Risk (traffic fatalities)
LLW (B) [a]	LANL to Pojoaque	0.000309	1.85×10^{-7}	0.0000938	5.63×10^{-8}	3.95×10^{-10}	7.34×10^{-7}
LLW (D) [b]		0.000371	2.23×10^{-7}	0.000159	9.55×10^{-8}	5.16×10^{-10}	7.34×10^{-7}
High activity [c]		0.000309	1.85×10^{-7}	0.0000938	5.63×10^{-8}	3.95×10^{-10}	7.34×10^{-7}
LLW (RH) [d]		0.000269	1.61×10^{-7}	0.0000486	2.92×10^{-8}	4.84×10^{-15}	7.34×10^{-7}
DD&D bulk [e]		0.0000340	2.04×10^{-8}	6.56×10^{-6}	3.94×10^{-9}	2.66×10^{-12}	7.34×10^{-7}
LSA		0.0000340	2.04×10^{-8}	6.56×10^{-6}	3.94×10^{-9}	1.92×10^{-10}	7.34×10^{-7}
CH-TRU		0.00118	7.08×10^{-7}	0.000384	2.30×10^{-7}	4.25×10^{-12}	7.34×10^{-7}
RH-TRU		0.00179	1.08×10^{-6}	0.000486	2.92×10^{-7}	9.87×10^{-14}	7.34×10^{-7}
SNM [f]		0.000298	1.79×10^{-7}	0.000336	2.02×10^{-7}	5.92×10^{-12}	8.33×10^{-8}
PuO_2 [g]		0.000090	5.40×10^{-8}	0.000090	5.4×10^{-8}	2.89×10^{-10}	8.33×10^{-8}
PuO_2 [h]		0.00045	2.70×10^{-7}	0.00030	1.80×10^{-7}	6.16×10^{-10}	8.33×10^{-8}
U-233		0.00067	4.02×10^{-7}	0.000889	5.33×10^{-7}	1.05×10^{-11}	8.33×10^{-8}
LLW (B) [a]	Pojoaque to Santa Fe [i]	0.000517	3.10×10^{-7}	0.000154	9.22v$\times 10^{-8}$	6.31×10^{-10}	1.23×10^{-6}
LLW (D) [b]		0.000622	3.73×10^{-7}	0.000261	1.56×10^{-7}	8.25×10^{-10}	1.23×10^{-6}
High activity [c]		0.000517	3.10×10^{-7}	0.000154	9.22×10^{-8}	6.31×10^{-10}	1.23×10^{-6}
LLW (RH) [d]		0.000450	2.70×10^{-7}	0.0000797	4.78×10^{-8}	5.62×10^{-15}	1.23×10^{-6}
DD&D bulk [e]		0.0000569	3.42×10^{-8}	0.0000108	6.45×10^{-9}	3.09×10^{-12}	1.23×10^{-6}
LSA		0.0000569	3.42×10^{-8}	0.0000108	6.45×10^{-9}	2.23×10^{-10}	1.23×10^{-6}
CH-TRU		0.00198	1.19×10^{-6}	0.000629	3.77×10^{-7}	4.94×10^{-12}	1.23×10^{-6}
RH-TRU		0.00300	1.80×10^{-6}	0.000797	4.78×10^{-7}	1.15×10^{-13}	1.23×10^{-6}
SNM [f]		0.000500	3.00×10^{-7}	0.000552	3.31×10^{-7}	1.45×10^{-11}	1.40×10^{-7}
PuO_2 [g]		0.000151	9.05×10^{-8}	0.000138	8.28×10^{-8}	8.49×10^{-10}	1.40×10^{-7}
PuO_2 [h]		0.000754	4.53×10^{-7}	0.000493	2.96×10^{-7}	1.81×10^{-9}	1.40×10^{-7}
U-233		0.00112	6.74×10^{-7}	0.00146	8.73×10^{-7}	3.10×10^{-11}	1.40×10^{-7}

LCF = latent cancer fatality, LLW = low-level radioactive waste, RH = remote-handled, DD&D = decontamination, decommissioning, and demolition, LSA = low specific activity waste, CH = contact-handled, TRU = transuranic waste, SNM = special nuclear material, PuO_2 = plutonium dioxide, U-233 = uranium-233.

[a] Low-level radioactive waste transported in Type A B-25 boxes.

[b] Low-level radioactive waste transported in 55-gallon (208-liter) drums.

[c] High activity low-level radioactive waste containing more than 10 nanocuries per gram of transuranic waste transported in Type A, B-25 boxes. This waste is comparable to Class B or Class C of 10 CFR Part 61 waste classification.

[d] Remote-handled low-level radioactive waste transported in 55-gallon (208-liter) drums.

[e] Decommissioning and demolition bulk managed waste, with a radioactive inventory of equivalent 0.0001 curies of plutonium-239 per cubic yard.

[f] Calculations are based on the shipment transport index of 5. Transport indices for SNM shipments are 1 and 5, as explained in Section K.5.1.

[g] Polished plutonium oxide (very low decay impurities).

[h] Unpolished plutonium oxide (high concentration of decay impurities).

[i] Shipments pass through the Santa Fe bypass (New Mexico 599) to Interstate 25.

All radioactive material transports would pass through the LANL to Pojoaque route segment, and those that would be destined for the Nevada Test Site, WIPP, Savannah River Site, and Pantex would pass through the second segment; that is, Pojoaque to Santa Fe. Therefore, the populations in these route segments would receive the maximum impacts.

In these tables, 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 of people to external radiation emanating from the packaged radioactive materials. The exposed population includes the off-link public (people living along the route), on-link public (pedestrian and car occupants along the route) and public at rest and fuel stops. Doses are calculated for the crew and public (people living along the route, pedestrians and drivers along the route, and the public at rest and fueling stops). For onsite shipments, the stop dose (doses to the public at rest and refueling stops) is set at zero, because a truck is not expected to stop during a shipment that takes less than an hour. For transportation accidents, the risk factors are given for both the radiological, in terms of potential LCF in the exposed population, and the nonradiological, in terms of number of traffic fatalities. The LCF represents the number of additional latent fatal cancers among the exposed population.

Both the radiological dose risk factor and the nonradiological risk factor for transportation accidents are presented in Tables K–3 and K–4. The radiological and nonradiological accident risk factors are provided in terms of potential fatalities per shipment. The radiological risks are in terms of LCFs. For the population, the radiological risks were calculated by multiplying the accident dose risks by the health risk factor of 6×10^{-4} latent cancer fatalities per person-rem of exposure. The nonradiological risk factors are nonoccupational traffic fatalities resulting from transportation accidents.

As stated earlier (see Section K.6.3), the accident dose is called "dose risk" because the values incorporate the spectrum of accident severity probabilities and associated consequences (such as dose). The accident dose risks are very low because accident severity probabilities (the likelihood of accidents leading to confinement breach of a package or shipping cask and release of its contents) are small, and the content and form of the wastes (solid dirt-like contamination) are such that would lead to nondispersible and mostly noncombustible release. Although persons reside in a 50-mile (80-kilometer) radius along the transportation route, they are generally quite far from the route. Because RADTRAN 5 uses an assumption of homogeneous population, it would greatly overestimate the actual doses.

At LANL, radioactive materials are transported both on site, between the Technical Areas (TAs), and off site to multiple locations. Onsite transport constitutes the majority of activities that are part of routine operations in support of various programs. The radioactive materials transported onsite between TAs are mainly of limited quantities, short travel distances, and frequently on closed roads. The impacts of these activities are part of the normal operations at these areas. For example, worker dose from handling and transporting the radioactive materials are included as part of operational activities. Specific analyses performed in the *1999 SWEIS* (DOE 1999a) indicated that the projected collective radiation dose for LANL drivers from a projected 10,750 onsite shipments to be 10.3 person-rem per year, or on the average, less than one millirem per transport. Review of the onsite radioactive materials transportation within the last 4 years indicates a much smaller number of shipments than those projected in the *1999 SWEIS*. Therefore, the *1999 SWEIS* projection of impacts would envelop the impacts for the routine onsite transportation. The nonroutine onsite transport activities, such as waste transport from facility decommissioning and demolition or from MDA remediation, were evaluated and presented in the SWEIS where applicable.

Offsite transports would occur using both trucks and air freight. Materials transported by air freight would be similar in number, type, and forms as those considered in the *1999 SWEIS*, and would hence result in similar impacts. The aircrew dose from air freight radioactive transport was estimated at 2.4 person-rem per year (DOE 1999a). Therefore, only truck (both commercial and DOE safe secure trailer) transport is analyzed here. The *1999 SWEIS* provides a comprehensive listing of various radioactive material types, forms, origin-destination, quantities and the projected number of shipments. The radioactive materials transported included tritium, plutonium, uranium (both depleted and enriched), offsite source recovery project sealed sources, medical isotopes, small quantities of activation products, low-level radioactive waste, and transuranic waste. The specific origins-destinations, except for Rocky Flats, are expected to be applicable for future transports. For analysis purposes in this SWEIS, the focus was on those origins-destinations that would have the greatest effect, including Pantex and Savannah River Site (for plutonium transports) and waste disposal sites (such as the Nevada Test Site, a commercial site in Utah, and WIPP). Transports of other radioactive materials would remain similar to those projected in the *1999 SWEIS*.

Table K–5 provides the estimated number of shipments for various materials under each alternative. In addition, this table provides the estimated number of shipments from activities associated with the MDA removal and capping options and those resulting from increase in pit production from 20 to 80 pits per year. The waste shipments under the No Action Alternative include those expected to be generated during LANL operations over the next 10 years (between 2007 and 2016), baseline remediation of MDAs, and transport of transuranic wastes currently stored above ground. The shipments under the Expanded Operations Alternative include operational wastes, the TA-18 and TA-21 decommissioning and demolition wastes, demolition and refurbishment wastes from implementation of selected project-specific actions as detailed in Appendices G and H, and a range of generated wastes from remediation options on MDAs as detailed in Appendix I. The MDA remediation options include capping and remediation, and removal and remediation of various MDAs and other potential release sites under the Consent Order. The shipments under the Reduced Operations Alternative include generated wastes from LANL operations, the TA-18 decommissioning and demolition activities, and baseline remediation of MDA activities. For the remediation options for MDAs, see Appendix I. In addition, Table K-5 provides the required number of shipments of special nuclear material in support of pit production and Advanced Recovery and Integrated Extraction System, uranium-233 for the criticality safety program, and polished plutonium oxides for the mixed oxide fabrication program under each alternative, as applicable.

LANL currently possess about 16.5 pounds (7.5 kilograms) of uranium-233 metal and oxides. The impacts of shipping about 9.9 to 11 pounds (4.5 to 5 kilograms) of these materials to Oak Ridge National Laboratory for processing and disposition are evaluated in the LANL SWEIS. Further investigation of the uranium-233 needs has identified that 6.2 pounds (2.8 kilograms) are considered surplus, of which 0.5 pounds (240 grams) may not meet acceptance requirements at Oak Ridge National Laboratory. The revised requirement reduces the number of uranium-233 shipments to Oak Ridge, and therefore the current analysis encompasses the impacts of the proposal to transport a lesser quantity.

Table K–5 Estimates of the Number of Radioactive Shipments Under Each Alternative and Selected Activities

Alternative (Activities)	*Number of Shipments*										
	Radioactive Materials									*Miscellaneous*	
	LSA	*DD&D Bulk*	*LLW (B)* [a]	*High Activity* [b]	*LLW-RH* [c]	*Mixed LLW*	*TRU* [d]	*SNM*	*PuO_2*	*Hazardous*	*Others* [e]
No Action	624	812	9,217	312	0	196	1,460	958	20	946	10,778
Reduced Operations	624	812	7,883	312	0	196	1,460	958	20	932	10,778
Expanded Operations [f]	1,436-49,940	9,538	9,919	3,418-36,521	196-856	297-9,019	2,405-5,044	1,558	50	2,781-4,749	35,419-41,506
Expanded Operations (without MDA Remediation) [g]	681	9,538	9,919	3,418	196	240	2,397	1,558	50	1,000	31,856
(MDA Remediation) [h]	755-49,259	0	0	0-33,103	0-660	57-8,779	8-2,647	0	0	1,781-3,749	3,563-9,650
(Increase in Pit Production) [i]	0	0	701	0	0	6	246	600	0	0	0

LSA = low specific activity, DD&D = decontamination, decommissioning, and demolition, LLW = low-level radioactive waste, RH = remote handled, TRU = transuranic waste, SNM = special nuclear material, PuO_2 = plutonium dioxide.

[a] Low-level radioactive waste transported in drums or Type A, B-25 boxes. The values here also include shipments of evaporator bottoms from Radioactive Liquid Waste Treatment Facility to an offsite location and the returned dried wastes.

[b] High activity low-level radioactive waste containing more than 10 nanocuries per gram of transuranic waste transported in Type A, B-25 boxes. This waste is comparable to Class B or Class C of 10 CFR Part 61 waste classification. This waste is generated during MDA waste retrieval, and from decontamination and demolishing of some of the buildings. The shipments also include one shipment of strontium-90 radioisotope thermoelectric generators under all alternatives.

[c] Remote-handled low-level radioactive waste transported in 55-gallon (208-liter) drums.

[d] The sum of remote-handled and contact-handled transuranic waste shipments.

[e] Others include industrial, sanitary, and asbestos wastes.

[f] The range of values represent the estimated number of shipments for options of capping and remediation and removal and remediation of all MDAs.

[g] Expanded Operations Alternative with baseline MDA remediation (without capping or removal).

[h] The range values represent the estimated number of shipments for options of capping and removal of all MDAs.

[i] The waste shipment values presented are based on the differences between the No Action and the Expanded Operation Alternatives' projected waste volumes for routine operation.

In order to provide flexibility for potential disposition of all surplus uranium-233 at WIPP, per shipment and total transportation impacts for shipment of 6.2 pounds (2.8 kilograms) uranium-233 to WIPP is provided in this appendix. The surplus materials are assumed to be packaged in pipe overpack containers and shipped as remote-handled transuranic waste. Pipe overpack containers could be transported in either of two certified casks; 10 drums per cask could be transported in the CNS10-160 B or 3 drums per cask could be transported in the RH-72B. For purposes of analysis, it was assumed that the RH-72B cask, which results in a higher number of shipments, would be used. The per-shipment doses and risks to the transport crew and the population are provided in Table K–3. Use of RH-72B cask would require a total of 63 shipments. Therefore, the total dose to the crew and population would be 2.18 and 0.58 person-rem, respectively. This is small fraction of the total dose under any one of the alternatives analyzed.

Table K–6 shows the risks of transporting radioactive materials under each alternative, and for the MDA remediation options and the increased pit production activities. The risks are 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 risks are for the total offsite transport of the radioactive materials between 2007 and 2016. The risks to the individuals and population from transport of radioactive materials beyond 2016 would be slightly greater than those provided under the No Action Alternative.

Table K–6 Ten-Year Risks of Transporting Radioactive Materials Under Each Alternative and Selected Activities

				Incident-Free				Accident	
				Crew		Population			
Transport Segments	*Offsite Disposal Option* [a]	*Number of Shipments*	*Round Trip Kilometers Traveled (million)*	*Dose (person-rem)*	*Risk* [b]	*Dose (person-rem)*	*Risk* [b]	*Radiological Risk* [b]	*Nonradiological Risk* [b]
No Action									
LANL to Pojoaque	NTS	13,599	0.85	5.04	0.00303	1.81	0.00109	3.9×10^{-6}	0.0093
Pojoaque to Santa Fe		13,599	1.15	8.77	0.00526	3.29	0.00198	7.1×10^{-6}	0.0164
Total		13,599	31.88	163.75	0.09825	58.37	0.03502	0.00017	0.3041
LANL to Pojoaque	Commercial	13,599	0.85	5.04	0.00303	1.81	0.00109	3.9×10^{-6}	0.0093
Pojoaque to Santa Fe		2,893 [c]	0.30	3.89	0.00233	1.85	0.00111	1.1×10^{-6}	0.0032
Total		13,599	28.16	147.30	0.08838	52.99	0.03179	0.00014	0.263
Reduced Operations									
LANL to Pojoaque	NTS	12,265	0.76	4.63	0.00278	1.69	0.00101	3.4×10^{-6}	0.0088
Pojoaque to Santa Fe		12,265	1.05	8.08	0.00485	3.09	0.00185	6.2×10^{-6}	0.0147
Total		12,265	28.54	147.17	0.08830	53.14	0.03188	0.00015	0.271
LANL to Pojoaque	Commercial	12,265	0.76	4.63	0.00278	1.69	0.00101	3.4×10^{-6}	0.0088
Pojoaque to Santa Fe		2,893 [c]	0.30	3.89	0.00233	1.85	0.00111	1.1×10^{-6}	0.0032
Total		12,265	25.28	133.05	0.07983	48.53	0.02912	0.00013	0.235
Expanded Operations (with MDA Removal Option)									
LANL to Pojoaque	NTS	122,445	7.62	25.94	0.01556	8.14	0.00488	0.000032	0.089
Pojoaque to Santa Fe		122,445	9.70	43.46	0.02608	13.31	0.00799	0.000047	0.149
Total		122,445	299.94	910.31	0.54619	286.77	0.17206	0.0016	2.96
LANL to Pojoaque	Commercial	122,445	7.62	25.94	0.01556	8.14	0.00488	0.000032	0.089
Pojoaque to Santa Fe		44,205 [c]	3.52	30.37	0.01822	9.79	0.00587	0.000024	0.0532
Total		122,445	272.76	866.16	0.51970	273.62	0.16417	0.0014	2.67
Expanded Operations (with MDA Capping Option)									
LANL to Pojoaque	NTS	28,817	1.79	8.04	0.00482	2.84	0.00171	5.7×10^{-6}	0.0205
Pojoaque to Santa Fe		28,817	2.31	13.47	0.00808	4.64	0.00278	9.8×10^{-6}	0.0343
Total		28,817	69.28	255.88	0.15353	89.07	0.05344	0.00025	0.660
LANL to Pojoaque	Commercial	28,817	1.79	8.04	0.00482	2.84	0.00171	5.7×10^{-6}	0.0205
Pojoaque to Santa Fe		7,803 [c]	0.65	7.65	0.00459	2.98	0.00179	3.1×10^{-6}	0.0085
Total		28,817	61.98	236.26	0.14175	82.86	0.04972	0.00022	0.580

Transport Segments	Offsite Disposal Option [a]	Number of Shipments	Round Trip Kilometers Traveled (million)	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk [b]	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk [b]	Accident: Radiological Risk [b]	Accident: Nonradiological Risk [b]
Expanded Operations (without MDA Removal or Capping Options)									
LANL to Pojoaque	NTS	27,997	1.74	7.98	0.00479	2.83	0.00170	5.5×10^{-6}	0.0199
Pojoaque to Santa Fe		27,997	2.24	13.38	0.00803	4.62	0.00277	9.6×10^{-6}	0.0333
Total		27,997	67.24	253.96	0.15237	88.58	0.05315	0.00024	0.640
LANL to Pojoaque	Commercial	27,997	1.74	7.98	0.00479	2.83	0.00170	5.5×10^{-6}	0.0199
Pojoaque to Santa Fe		7,795 [c]	0.64	7.63	0.00458	2.97	0.00178	3.1×10^{-6}	0.0085
Total		27,997	60.22	234.58	0.14075	82.44	0.04946	0.00021	0.563
MDA Removal Option Activities									
LANL to Pojoaque	NTS	94,448	5.87	17.95	0.01077	5.31	0.00319	0.000026	0.069
Pojoaque to Santa Fe		94,448	7.46	30.08	0.01805	8.70	0.00522	0.000037	0.088
Total		94,448	232.70	656.35	0.39381	198.19	0.11892	0.0013	2.320
LANL to Pojoaque	Commercial	94,448	5.87	17.95	0.01077	5.31	0.00319	0.000026	0.069
Pojoaque to Santa Fe		36,410 [c]	2.88	22.73	0.01364	6.82	0.00409	0.000021	0.034
Total		94,448	212.54	631.58	0.37895	191.18	0.11471	0.0012	2.100
MDA Capping Option Activities									
LANL to Pojoaque	NTS	820	0.05	0.05	0.00003	0.01	0.00001	1.7×10^{-7}	0.0006
Pojoaque to Santa Fe		820	0.06	0.09	0.00005	0.02	0.00001	2.0×10^{-7}	0.00076
Total		820	2.04	1.92	0.00115	0.49	0.00029	0.00001	0.0203
LANL to Pojoaque	Commercial	820	0.05	0.05	0.00003	0.01	0.00001	1.7×10^{-7}	0.00060
Pojoaque to Santa Fe		8 [c]	0.0006	0.02	0.00001	0.005	0.000003	3.9×10^{-11}	0.00001
Total		820	1.76	1.68	0.00101	0.42	0.00025	0.000008	0.0172
Increase in Pit Production Activities									
LANL to Pojoaque	NTS	1,553	0.097	0.68	0.00041	0.36	0.00022	2.7×10^{-7}	0.00075
Pojoaque to Santa Fe		1,553	0.15	1.14	0.00068	0.59	0.00035	1.9×10^{-6}	0.00125
Total		1,553	3.63	18.0	0.01083	8.95	0.00537	0.000011	0.0239
LANL to Pojoaque	Commercial	1,553	0.097	0.68	0.00041	0.36	0.00022	2.7×10^{-7}	0.00075
Pojoaque to Santa Fe		879 [c]	0.08	0.79	0.00047	0.49	0.00029	1.4×10^{-6}	0.00043
Total		1,553	3.39	16.87	0.01012	8.56	0.00514	9.6×10^{-6}	0.0214

NTS = Nevada Test Site, MDA = material disposal area.

[a] Under this option, low-level radioactive waste would be shipped to either the Nevada Test Site or a commercial site in Utah. Transuranic wastes would be shipped to WIPP. Pantex, Y-12, Oak Ridge, Nevada Test site, Lawrence Livermore and the Savannah River Site would ship or receive special nuclear materials. Also note that the number of shipments along the Pojoaque to Santa Fe segment would be lower when the commercial site in Utah is used as an offsite disposal option for low-level radioactive waste.

[b] Risk is expressed in terms of latent cancer fatalities, except for the nonradiological risk, where it refers to the number of traffic accident fatalities.

[c] Shipments of low-level radioactive waste to a commercial disposal site in Utah would not pass along the Pojoaque to Santa Fe segment of highway.

The values presented in Table K–6 show that the total radiological risks (the product of consequence and frequency) are very small under all alternatives. It should be noted that the maximum annual dose to a transportation worker would be 100 millirem per year, unless the individual is a trained radiation worker who would have an administratively controlled annual dose limit of 2,000 millirem (DOE 1999b). The potential for a trained radiation worker to develop a latent fatal cancer from the maximum annual exposure is 0.0012 (about 1 chance in 800). Therefore, no individual transportation worker would be expected to develop a latent fatal cancer from exposures during the activities under all alternatives.

Nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks. Considering that the transportation activities analyzed in this SWEIS would occur over a 10-year period and the average number of traffic fatalities in the United States is about 40,000 per year (DOT 2006), the traffic fatality risk under all alternatives would be very small.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for hypothetical exposure scenarios identified in Section K.5.3. The estimated doses to workers and the public are presented in **Table K–7**. 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 is based on the same individual being responsible for 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 remote-handled transuranic waste for one-half hour is calculated to be 0.012 rem (12 millirem). This is considered a one-time event for that individual.

Table K–7 Estimated Dose to Maximally Exposed Individuals During Incident-Free Transportation Conditions

Receptor	*Dose to Maximally Exposed Individual*
Workers	
Crewmember (truck drivers)	2 rem per year [a]
Inspector	0.028 rem per event per hour of inspection
Public	
Resident (along the truck route)	3.0×10^{-7} rem per event
Person in traffic congestion	0.012 rem per event per one-half hour stop
Persons at a rest stop or gas station	0.00020 rem per event per hour of stop
Gas station attendant	0.00026 rem per event

[a] Maximum administrative dose control level per year for a trained radiation worker (truck crewmember).

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 is calculated assuming that the resident is present for every shipment and is unshielded at a distance of about 98 feet (30 meters) from the route. Therefore, the cumulative dose depends on the number of shipments passing a particular point and is independent of the actual route being considered. If one assumes the maximum resident dose provided in Table K–7 for all transports, then the maximum dose to this resident would be about 37 millirem if all radioactive materials were shipped via this route. This dose corresponds to that for shipments under the Expanded Operations Alternative with the MDA

Removal Option, which has an estimated number of shipments of about 122,450 over 10 years. This dose translates to less than 4 millirem per year, with a risk of developing a latent fatal cancer of 2.4×10^{-6} per year (or one chance in 41,700 that the exposed individual would develop a latent fatal cancer from exposure to all shipments over 10 years).

The accident risk assessment and the impacts shown in Table K–6 take into account the entire spectrum of potential accidents, from a fender-bender to extremely severe accidents. To provide additional insight into the severity of accidents in terms of the potential dose to a MEI and the public, an accident consequence assessment has been performed for a maximum reasonably foreseeable hypothetical transportation accident with a likelihood of occurrence greater than 1 in 10 million per year. The results, presented in Table K–6, include all conceivable accidents, irrespective of their likelihood.

The following assumptions were used to estimate the consequences of maximum reasonably foreseeable offsite transportation accidents:

- The accident is the most severe with the highest release fraction; high-impact and high-temperature fire accident (highest severity category).
- The individual is 330 feet (100 meters) downwind from a ground release accident.
- The individual is exposed to airborne contamination for 2 hours and ground contamination for 24 hours with no interdiction or cleanup. A stable weather condition (Pasquill Stability Class F) with a wind speed of 1 meter per second (2.2 miles per hour) is considered.
- The population is assumed at a uniform density to a radius of 50 miles (80 kilometers), and exposed to the entire plume passage and 7 days of ground exposure without interdiction and cleanup. A neutral weather condition (Pasquill Stability Class D) with a wind speed of 4 meters per second (8.8 miles per hour) is considered. Since the consequences are proportional to the population density, the accident is assumed to occur in an urban area with the highest density, see Table K–1.
- The number of containers involved in the accident is listed in Table K–2. When multiple Type B or shielded Type A shipping casks are transported in a shipment, a single cask is assumed to have failed in the accident. It is unlikely that a severe accident would breach multiple casks.

Table K–8 provides the estimated dose and risk to an individual and population from a maximum foreseeable truck or rail transportation accident with the highest consequences under each alternative and disposal option.

Table K–8 Estimated Dose to the Population and to Maximally Exposed Individuals during Most Severe Accident Conditions

Alternative	Material in the Accident With the Highest Consequences	Likelihood of the Accident (per year) [a]	Population [a]		Maximally Exposed Individual [b]	
			Dose (person-rem)	Risk (LCF)	Dose (rem)	Risk (LCF)
No Action	CH-TRU	1.9×10^{-7}	310	0.186	0.0062	3.7×10^{-6}
Reduced Operations	CH-TRU	1.9×10^{-7}	310	0.186	0.0062	3.7×10^{-6}
Expanded Operations, MDA Removal Option	CH-TRU	5.2×10^{-7}	310	0.186	0.0062	3.7×10^{-6}
Expanded Operations, MDA Capping Option [c]	CH-TRU	2.7×10^{-7}	310	0.186	0.0062	3.7×10^{-6}

LCF = latent cancer fatality, CH-TRU = contact-handled transuranic waste, MDA = material disposal area.

[a] The population doses, risks, and the likelihood of the accident are presented for an urban area on the transportation route. Population extends at a uniform density to a radius of 50 miles (80 kilometers). The weather condition was assumed to be Pasquill Stability Class D with a wind speed of about 9 miles per hour (4 meters per second).

[b] The individual is assumed to be 330 feet (100 meters) downwind from the accident and exposed to the entire plume of the radioactive release. The weather condition is assumed to be Pasquill Stability Class F with a wind speed of 2.2 miles per hour (1 meter per second).

[c] The values presented here are also applicable to Expanded Operations without MDA removal or capping.

K.8 Impact of Construction and Hazardous Material Transport

This section evaluates the impacts of transporting materials required to construct new facilities, as well as nonradioactive and hazardous materials generated during each alternative. The construction materials considered are concrete, cement, sand, gravel, dirt, and steel. The impacts were evaluated based on the number of truck shipments required for each of the materials and the distances from their point of origin to the LANL site. The origins of construction materials were assumed to be at an average distance of 100 miles (160 kilometers) from the site. The truck kilometers for all material shipments under each alternative were calculated by summing all of the activities from construction through closure (where applicable). The truck accident and fatality rates were assumed to be those that were provided earlier for the onsite and local area transports. **Table K–9** summarizes the impacts in terms of total number of kilometers, accidents, and fatalities for all alternatives. The results in Table K–9 indicate that there are no large differences in the impacts among all alternatives. Under all alternatives, the expected potential traffic fatalities are very low.

Table K–9 Estimated Impacts of Construction and Operational Material Transport

Alternative	Total Distance Traveled (kilometers)	Number of Accidents	Number of Fatalities
No Action	5.67×10^{6}	0.64	0.070
Reduced Operations	5.53×10^{6}	0.62	0.070
Expanded Operations			
Without MDA Capping or Removal	22.08×10^{6}	2.50	0.26
With MDA Capping	24.52×10^{6}	2.77	0.29
With MDA Removal	28.12×10^{6}	3.18	0.33

MDA = material disposal area.

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

K.9 Conclusions

Based on the results presented in the previous section, the following conclusions have been reached (see Tables K–5 through K–9):

- It is unlikely that the transportation of radioactive waste would cause an additional fatality as a result of radiation either from incident-free operation or postulated transportation accidents.
- The highest risk to the public would be under the Expanded Operations Alternative (with the MDA Removal Option) and the Nevada Test Site disposal site option, where about 122,450 truck shipments of radioactive materials would be transported to the Nevada Test Site, WIPP, Pantex, Lawrence Livermore National Laboratory, Oak Ridge (Y-12 Complex and K-25), and the Savannah River Site.
- The lowest risk to the public would be under the Reduced Operations Alternative and a commercial site disposal option, with about 12,270 truck shipments of radioactive materials to similar locations as those in the Expanded Operations Alternative.

The nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks. The maximum risks would occur under the Expanded Operations Alternative (with the MDA Removal Option) and the Nevada Test Site disposal site option. Considering that the transportation activities would occur over a 10-year period and that 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.

K.10 Long-Term Impacts of Transportation

The *Yucca Mountain EIS* (DOE 2002a, 2007) analyzed the cumulative impacts of the transportation of radioactive material, consisting of impacts of historical shipments of radioactive waste and spent nuclear fuel, reasonably foreseeable actions that include transportation of radioactive material, and general radioactive material transportation that is not related to a particular action. The collective dose to the general population and workers was the measure used to quantify cumulative transportation impacts. This measure of impact was chosen because it may be directly related to LCFs using a cancer risk coefficient. **Table K–10** provides a summary of 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, the alternatives, reasonably foreseeable actions, and general transportation) was estimated to be about 382,400 person-rem (229 LCFs) for the period 1943 through 2073 (131 years). The total general population collective dose was estimated to be about 343,900 person-rem (206 LCFs). The majority of the collective dose for workers and the general population was due to the general transportation of radioactive material. Examples of these activities are shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level waste to commercial disposal facilities. The total number of LCFs (among the workers and the general population) estimated to result from radioactive material transportation over the period between 1943 and 2073 is about 435, or an average of less than

4 LCFs per year. Over this same period (131 years), approximately 73 million people would die from cancer, based on the National Center for Health Statistics data on the average annual number of cancer death in the United States of about 554,000, with less than 1 percent fluctuation in the number of cancer fatalities in any given year (CDC 2007). The transportation-related LCFs would be 0.0006 percent of the total number of cancers, therefore, it is indistinguishable from the natural fluctuation in the total annual death rate from cancer.

Table K–10 Cumulative Transportation-Related Radiological Collective Doses and Latent Cancer Fatalities (1943 to 2073)

Category	*Collective Worker Dose (person-rem)*	*Collective General Population Dose (person-rem)*
Transportation Impacts in this SWEIS [a]	910 [a]	287 [a]
Other Nuclear Material Shipments		
Historical	330	230
Reasonably Foreseeable Actions [b]	25,300	42,200
General Radioactive Material Transport (1943 to 2073)	350,000	300,000
Yucca Mountain EIS [c] (maximum transport) (up to 2073)	5,900	1,200
Total collective dose [d] (up to 2073)	382,400	343,900
Total latent cancer fatalities	229	206

[a] Maximum values from Tables K–6 for transports from 2007 through 2016.
[b] Includes transportation impacts associated with Complex Transformation activities related to radioactive material transports (DOE 2007b, Table 6.3.2-1).
[c] Impacts for the Proposed Action in the *Draft Yucca Mountain Supplemental EIS* (DOE 2007, Table 8-14). [Similar impacts in the *Yucca Mountain EIS* (DOE 2002a) were 4600, and 1,600 person-rem for workers and population, respectively.] If DOE decides to expand the program to include all potential high-level and Greater-Than-Class C wastes and spent nuclear fuel (implement inventory Module 2), then the worker and public doses would be about 15,000 and 2,700 person-rem, respectively.
[d] The values are rounded to the nearest hundred.
Source: DOE 2002a, 2007.

K.10.1 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 estimating 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 (such as the approximate algorithms used in the computer programs used for the analyses).

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, the 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 is 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 are addressed. Where practical, the parameters that most affect the risk assessment results are identified.

K.10.2 Uncertainties in Material Inventory and Characterization

The inventories and physical and radiological characteristics are important input parameters to the transportation risk assessment. The potential number of shipments for all alternatives is 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 inventory and characterization are reflected in the transportation risk results. If the inventory is overestimated (or underestimated), the resulting transportation risk estimates are also overestimated (or underestimated) by roughly the same factor. However, the same inventory estimates are used to analyze the transportation impacts of each of the alternatives. Therefore, for comparative purposes, the observed differences in transportation risks among the alternatives, as given in Table K–6, are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

K.10.3 Uncertainties in Containers, Shipment Capacities, and Number of Shipments

The transportation required for each alternative is based in part on assumptions concerning the packaging characteristics and shipment capacities for commercial trucks. Representative 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 alternatives would remain about the same.

K.10.4 Uncertainties in Route Determination

Analyzed routes have been determined between all origin and destination sites considered in the SWEIS. The routes have been determined to be 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 representative ones with regard to distances and total population along the routes. Moreover, because materials could be transported over an extended time starting at some time in the future, the highway infrastructure and the demographics along routes could change. These effects have not been accounted for in the transportation assessment; however, it is not anticipated that these changes would substantially affect relative comparisons of risk among the alternatives considered in the SWEIS. Specific routes for certain shipments cannot be identified in advance because the routes are classified to protect national security interests.

K.10.5 Uncertainties in the Calculation of Radiation Doses

The models used to calculate radiation doses from transportation activities introduce a further uncertainty in 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 to 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 transportation routes, shipment surface dose rates, and individuals residing near the routes 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 a potential exists for an individual to be residing at the edge of the highway. It is clear that not all assumptions are accurate. For example, the off-link population is mostly heterogeneous, and the on-link traffic density varies widely within a geographic zone (urban, suburban, rural). Finally, added to this complexity are the assumptions regarding the expected distance between the public and the shipment at a traffic stop, rest stop, or traffic jam and the afforded shielding.

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

K.11 References

CDC (Centers for Disease Control and Prevention), 2007, "Total Number of Deaths for 113 Selected Causes, 1999-2004," National Center for Health Statistics, Hyattsville, Maryland, August.

DOE (U.S. Department of Energy), 1994, *DOE Handbook, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE-HDBK-3010-94, Washington, DC, December.

DOE (U.S. Department of Energy), 1996, *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel*, DOE/EIS-0218, Office of Environmental Management, Washington, DC, February.

DOE (U.S. Department of Energy), 1997, *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement*, DOE/EIS-0026-S-2, Carlsbad Area Office, Carlsbad, New Mexico, September.

DOE (U.S. Department of Energy), 1999a, *Site-Wide Environmental Impact Statement for Continued Operation of the Los Alamos National Laboratory, Los Alamos, New Mexico*, DOE/EIS-0238, Albuquerque Operations Office, Albuquerque, New Mexico, January.

DOE (U.S. Department of Energy), 1999b, *DOE Standard, Radiological Control*, DOE-STD-1098-99, Washington, DC, July.

DOE (U.S. Department of Energy), 2000, *Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility*, DOE/EIS-0310, Office of Nuclear Energy, Science and Technology, Washington, DC, December.

DOE (U.S. Department of Energy), 2002a, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250, Office of Civilian Radioactive Waste Management, Washington, DC, February.

DOE (U.S. Department of Energy), 2002b, *A Resource Handbook on DOE Transportation Risk Assessment*, DOE/EM/NTP/HB-01, Office of Environmental Management, National Transportation Program, Albuquerque, New Mexico, July.

DOE (U.S. Department of Energy), 2003a, *Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE), ISCORS Technical Report No. 1*, DOE/EH-412/0015/0802, Rev. 1, Office of Environmental Policy and Guidance, Washington, DC, January.

DOE (U.S. Department of Energy), 2003b, *West Valley Demonstration Project Waste Management Environmental Impact Statement*, DOE/EIS-0337, West Valley Area Office, West Valley, New York, December.

DOE (U.S. Department of Energy), 2007a, *Draft Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250F-S1D, Volume 1, Table 8-14, Office of Civilian Radioactive Waste Management, Las Vegas, Nevada, October.

DOE (U.S. Department of Energy), 2007b, *Draft Complex Transformation Supplemental Programmatic Environmental Impact Statement*, DOE/EIS-0236-S4, Section 6.3.2.3, National Nuclear Security Administration, Washington, DC, December.

DOT (U.S. Department of Transportation), 2003, *Comprehensive Truck Size and Weight Study*, Executive Summary, Federal Highway Administration, Washington, DC, May 19.

DOT (U.S. Department of Transportation), 2006, *Traffic Safety Facts 2004, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, DOT HS 809 919, National Center for Statistics and Analysis, National Highway Traffic Safety Administration, Washington, DC, January.

Grove (Grove Engineering), 2003, *MicroShield Version 6 User's Manual*, Rockville, Maryland, March.

Johnson, P. E., and R. D. Michelhaugh, 2003, *Transportation Routing Analysis Geographic Information System (TRAGIS) User's Manual*, ORNL/NTRC-006, Rev. 0, Oak Ridge National Laboratory, Oak Ridge, Tennessee, June.

LANL (Los Alamos National Laboratory), 2006, *Los Alamos National Laboratory Site-Wide Environmental Impact Statement Information Document*, Data Call Materials, Los Alamos, New Mexico.

Neuhauser, K. S., F. L. Kanipe, and R. F. Weiner, 2000, *RADTRAN 5 Technical Manual*, SAND2000-1256, Sandia National Laboratories, Albuquerque, New Mexico, May.

Neuhauser, K. S., and F. L. Kanipe, 2003, *RADTRAN 5 User Guide*, Revised by R. F. Weiner, SAND2003-2354, Sandia National Laboratories, Albuquerque, New Mexico, July.

NRC (U.S. Nuclear Regulatory Commission), 1977, *Final Environmental Statement on the Transportation of Radioactive Material By Air and Other Modes*, NUREG-0170, Vol. 1, Office of Standards Development, Washington, DC, December.

NRC (U.S. Nuclear Regulatory Commission), 1987, *Shipping Container Response to Severe Highway and Railway Accident Conditions*, NUREG/CR-4829, Vol. 1, UCID-20733, Washington, DC, Accessed through http://ttd.sandia.gov/nrc/docs.htm, February.

NRC (U.S. Nuclear Regulatory Commission), 2000, *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672, Vol. 1, SAND2000-0234, Office of Nuclear Material Safety and Safeguards, Washington, DC, Accessed through http://ttd.sandia.gov/nrc/docs.htm, March.

Phillips, J. S., D. B. Clauss, and D. F. Blower, 1994, *Determination of Influence Factors and Accident Rates for the Armored Tractor/Safe Secure Trailer*, SAND93-0111, Sandia National Laboratories, Albuquerque, New Mexico, April.

Rao, R. K., E. L. Wilmot, and R. E. Luna, 1982, *Non-Radiological Impacts of Transporting Radioactive Material*, SAND81-1703, Sandia National Laboratories, Albuquerque, New Mexico, February.

Saricks, C., and M. M. Tompkins, 1999, *State-Level Accident Rates of Surface Freight Transportation: A Reexamination*, ANL/ESD/TM-150, Center for Transportation Research, Argonne National Laboratory, Argonne, Illinois, April.

Yuan, Y. C., S. Y. Chen, B. M. Biwer, and D. J. LePoire, 1995, *RISKIND — A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel*, ANL/EAD-1, Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois, November.