APPENDIX E
EVALUATION OF HUMAN HEALTH EFFECTS FROM TRANSPORTATION

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E.1 Introduction

Transportation of any commodity involves a risk to both transportation crew members 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 transport 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, the human health risks associated with the transportation of radioactive materials and wastes, as well as nonradioactive hazardous waste, on public highways were assessed.

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, the analytical methods used for the risk assessment (e.g., computer models), and important assessment assumptions. In addition, to aid in understanding and interpreting the results, specific areas of uncertainty are described with an emphasis on how those uncertainties may 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.

E.2 Scope of Assessment

The scope of the transportation human health risk assessment, including transportation activities, potential radiological and nonradiological impacts, transportation modes, and receptors, is described in this section. This evaluation focuses on using offsite public highways. Additional details of the assessment are provided in the remaining sections of this appendix.

E.2.1 Transportation-related Activities

The transportation risk assessment is limited to estimating the human health risks related to transportation for each alternative. This includes incident-free risks related to being in the vicinity of a shipment during transport or at stops, as well as accident risks. The impacts of increased transportation levels on local traffic flow or infrastructure are addressed in Chapter 4, Section 4.1.3, Socioeconomics, of this *Surplus Plutonium Disposition Supplemental Environmental Impact Statement* (*SPD Supplemental EIS*).

E.2.2 Radiological Impacts

For each alternative, radiological risks (i.e., 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, or from an accident where there is no release of radioactive material but there is external radiation exposure to the unbreached container.

All radiological impacts are calculated in terms of radiation 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 [10 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 populations. The impacts are further expressed as health risks in terms of latent cancer fatalities (LCFs) in exposed individuals or populations using dose-to-risk conversion factors recommended by the Interagency Steering Committee on Radiation Standards guidance (DOE 2003b). A health risk conversion factor of 0.0006 LCFs per rem or person-rem of exposure is used for both the public and workers (DOE 2003b).

E.2.3 Nonradiological Impacts

In addition to radiological risks posed by transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., causes related to the transport vehicles, not the radioactive cargo). The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for accidents involving transport of radioactive and nonradioactive waste and construction materials. The nonradiological accident risk refers to the potential occurrence of transportation accidents that result in fatalities unrelated to the radioactive characteristics (e.g., radioactive nature) of the cargo.

Nonradiological risks during incident-free transportation conditions could also be caused by potential exposure to increased vehicle exhaust emissions. As explained in Section E.6.2, these emission impacts, in terms of excess latent mortalities, were not considered.

E.2.4 Transportation Modes

All shipments of radioactive and nonradioactive waste and construction materials are assumed to take place by exclusive-use truck. In addition to the use of commercial shippers for transport of radioactive waste and certain types of radioactive materials, shipment of several types of radioactive materials are assumed to occur using the National Nuclear Security Administration's (NNSA's) Secure Transportation Asset (STA), which consists of truck transport only. (No rail transport is analyzed because rail is not part of the NNSA's STA used to transport radioactive materials, and the radioactive wastes to be generated would not be transported in large enough quantities to justify rail.) Onsite and offsite shipments involving transport of special nuclear material[1] such as plutonium oxide or metal are assumed to occur using NNSA's STA. Transport of unirradiated mixed oxide (MOX) fuel is the responsibility of NNSA and for purposes of analysis is also assumed to occur using the STA. The NNSA Office of Secure Transportation has determined that contractor-provided transportation configurations for mixed oxide fuel assemblies can be conducted under the STA program using escorted, commercial trucks. See Appendix I, Section I.1.2.5, regarding impacts associated with this transportation. Note that the analysis in this *SPD Supplemental EIS* does not address the transport of used (irradiated) MOX fuel.

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[1] *Special nuclear material – as defined in Section 11 of the Atomic Energy Act: "(1) plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the U.S. Nuclear Regulatory Commission determines to be special nuclear material, or (2) any material artificially enriched by any of the foregoing."*

For the purpose of transporting special nuclear material, such as plutonium oxide or metal, the STA may use a specially designed tractor-trailer. Although details of vehicle enhancements and some operational aspects are classified, key characteristics are as follows (DOE 1999):

- Enhanced structural characteristics and a tie-down system to protect the cargo from impact
- Heightened thermal resistance to protect the cargo in case of fire
- Established operational and emergency plans and procedures governing the shipment of nuclear materials
- Federal agents who are armed Federal officers and have received vigorous specialized training
- An armored tractor component that provides Federal agent protection against attack and contains advanced communications equipment
- Specially designed escort vehicles containing advanced communications equipment and additional Federal agents
- 24-hour-a-day, real-time communications to monitor the location and status of all STA shipments
- Significantly more stringent maintenance standards than those for commercial transport equipment

E.2.5 Receptors

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck crew members 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 incident-free operation, the affected population includes individuals living within 800 meters (0.5 miles) of each side of the road. Potential risks are estimated for the affected populations and the hypothetical maximally exposed individual (MEI). For incident-free operation, the MEI would be a resident living near the highway who is exposed to all shipments transported on the road. For accident conditions, the affected population includes individuals residing within 80 kilometers (50 miles) of the accident, and the MEI would be an individual located 100 meters (330 feet) 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 various alternatives.

E.3 Packaging and Transportation Regulations

This section provides a high-level summary of radioactive materials packaging and transportation regulations. The packaging and transportation of radioactive materials are highly regulated. The U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC) have primary responsibility for Federal regulations governing commercial radioactive materials transportation. In addition, the U.S. Department of Energy (DOE) works with DOT and NRC in developing requirements and standards for radioactive materials transportation. DOE, including NNSA, has broad authority under the Atomic Energy Act of 1954, as amended, to regulate all aspects of activities involving radioactive materials that are undertaken by DOE or on its behalf, including the transportation of radioactive materials. However, in most cases that do not involve national security, DOE does not exercise its authority to regulate DOE shipments and instead utilizes commercial carriers that undertake shipments of DOE materials under the same terms and conditions as those used for commercial shipments. These shipments are subject to regulation by DOT and NRC. As a matter of policy, however, even in the limited circumstances where DOE exercises its Atomic Energy Act authority for shipments, DOE requirements mandate that all DOE shipments be undertaken in accordance with the requirements and standards that apply to comparable commercial shipments, unless there is a determination that national security or another critical interest requires different action.

The regulatory standards for packaging and transporting radioactive materials are designed to achieve the following 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)
- Provide physical protection against theft and sabotage during transit

The CFR details regulations pertaining to the transportation of radioactive materials published by DOT at 49 CFR Parts 106, 107, and 171–178; and NRC at 10 CFR Parts 20, 61, 71, and 73. For the U.S. Postal Service, Publication 52, “Hazardous, Restricted, or Perishable Mail,” specifies the quantities of radioactive material prohibited in surface mail. Interested readers are encouraged to visit the cited resources for the most current regulations or to review DOT’s *Radioactive Material Regulations Review* (DOT 2008) for a comprehensive discussion on radioactive material regulations.

E.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 used nuclear fuel, packaging must contain and shield the 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. Specific requirements for these packages are detailed in 49 CFR 173, Subpart I (“Class 7 [Radioactive] Materials”). All packages are designed to protect and retain their content under normal operations.

Excepted packaging is limited to transporting materials with extremely low levels of radioactivity and very low external radiation. Industrial packaging is 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 packaging is designed to protect and retain its contents under normal transport conditions; because it is used to transport materials with higher radioactive content, it must maintain sufficient shielding to limit radiation exposure to handling personnel. Type A packaging, typically a 0.21-cubic-meter (55-gallon) drum or standard waste box, is commonly used to transport radioactive materials with higher concentrations or amounts of radioactivity than materials transported in Excepted or Industrial packages. Type B packaging is used to transport material with the highest radioactivity levels and is designed to protect and retain its contents under transportation accident conditions (described in more detail in the following sections). Packaging requirements are an important consideration for transportation risk assessment.

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 and exclusive use provisions"), must be met. If the A1 or A2 limits are exceeded, the material must be shipped in a Type B package 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 a shipping container such as Industrial or Type A Packaging (49 CFR 173.427); see also DOT's *Radioactive Material Regulations Review* (DOT 2008). Type B packages, or casks, are subject to the radiation limits in 49 CFR 173.441.

Type A packaging is designed to retain its radioactive contents in normal transport. Design and test conditions that a Type A package must withstand include the following:

- 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 tests
- Impact of a 6-kilogram (13-pound) steel cylinder with rounded ends dropped from 1 meter (3.3 feet) onto the most vulnerable surface
- A compressive load of five times the mass of the gross weight of the package for 24 hours, or the equivalent of 13 kilopascals (1.9 pounds per square inch), multiplied by the vertically projected area of the package for 24 hours

Type B packaging is designed to retain its radioactive contents in both normal and accident conditions. In addition to the normal conditions outlined above, a Type B package must withstand accident conditions simulated by the following:

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

E.3.2 Transportation Regulations

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.

NRC regulates the packaging and transportation of radioactive material for its licensees, including commercial shippers of radioactive materials. In addition, under an agreement with DOT, NRC sets the standards for packages containing fissile materials and Type B 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 that meet those of DOT and NRC. DOT recognizes in 49 CFR 173.7(d) that 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.

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

E.4 Emergency Response

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

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

DHS has the authority to activate Nuclear Incident Response Teams, which include DOE Radiological Assistance Program Teams that can be dispatched from regional DOE Offices in response to a radiological incident. These teams provide first-responder radiological assistance to protect the health and safety of the general public, responders, and the environment and to assist in the detection, identification and analysis, and response to events involving radiological/nuclear material. Deployed teams provide traditional field monitoring and assessment support, as well as a search capability.

DOE uses DOE Order 151.1C, Comprehensive Emergency Management System, as a basis to establish a comprehensive emergency management program that provides detailed, hazard-specific planning and preparedness measures to minimize the health impacts of accidents involving loss of control over radioactive material or toxic chemicals. DOE provides technical assistance to other Federal agencies and to state and local governments. Contractors are responsible for maintaining emergency plans and response procedures for all facilities, operations, and activities under their jurisdiction and for implementing those plans and procedures during emergencies. Contractor and state and local government plans are fully coordinated and integrated. In addition, DOE established the Transportation Emergency Preparedness Program to ensure its operating contractors and state, tribal, and local emergency responders are prepared to respond promptly, efficiently, and effectively to accidents involving DOE shipments of radioactive material. This program is a component of the overall emergency management system established by DOE Order 151.1C.

In the event of a release of radiological cargo from a shipment along a route, DOE assumes that local emergency response personnel would be first to arrive at the accident scene. It is expected that response actions would be taken in context of the *Nuclear/Radiological Incident Annex*. Based on an initial assessment at the scene, their training, and available equipment, first responders would involve state and Federal resources as necessary. First responders and/or state and Federal responders would initiate actions in accordance with the DOT *2012 Emergency Response Guidebook* (DOT 2012a) to isolate the incident and perform any actions necessary to protect human health and the environment (such as evacuations or other means to reduce or prevent impacts to the public). Cleanup actions are the responsibility of the carrier. DOE would partner with the carrier, shipper, and applicable state and local jurisdictions to ensure cleanup actions meet regulatory requirements.

To mitigate the possibility of an accident, DOE issued DOE Manual 460.2-1A, *Radioactive Material Transportation Practices Manual for Use with DOE O 460.2A* (DOE 2008a). As specified in this manual, carriers are expected to exercise due caution and care in dispatching shipments. According to the manual, the carrier determines the acceptability of weather and road conditions, whether a shipment should be held before departure, and when actions should be taken while en route. The manual emphasizes that shipments should not be dispatched if severe weather or bad road conditions make travel hazardous. Current weather conditions, the weather forecast, and road conditions would be considered before dispatching a shipment. Conditions at the point of origin and along the entire route would be considered.

E.5 Methodology

The transportation risk assessment is based on the alternatives described in Chapter 2 of the *SPD Supplemental EIS*. **Figure E–1** summarizes the transportation risk assessment methodology. After the alternatives were identified and the requirements of the shipping campaign were understood, data were collected on material characteristics, transportation routes, and accident parameters.

Transportation impacts calculated for the *SPD Supplemental EIS* are presented in two parts: impacts from incident-free or routine transportation and impacts from transportation accidents. Impacts of incident-free transportation and transportation accidents are 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 originally 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 Transport 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 traffic fatalities. Incident-free risk is also expressed in terms of additional LCFs.

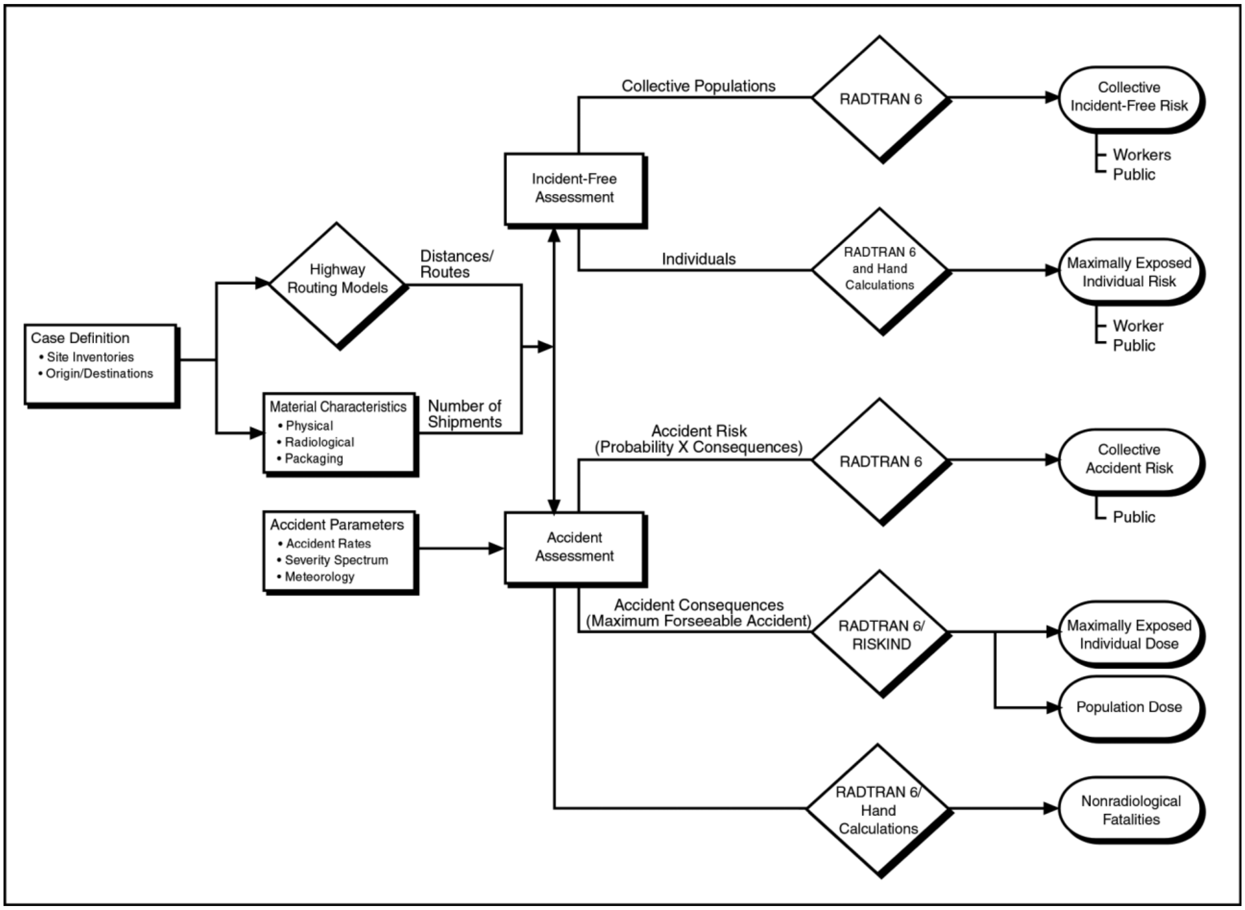

Figure E–1 Transportation Risk Assessment

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck crew members 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 was 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 identify routes and the associated distances and populations for purposes of analysis. This information, along with the properties of the material being shipped and route-specific accident frequencies, was entered into the Radioactive Material Transportation Risk Assessment (RADTRAN) 6 computer code (SNL 2009), which calculates incident-free transport and accident risks on a per-shipment basis. The risks under each alternative were determined by summing the products of per-shipment risks for each radioactive materials shipment type by the number of shipments of that material.

The RADTRAN 6 computer code was used for incident-free and accident risk assessments to estimate the impacts on populations, as well as for incident-free assessments associated with MEIs. RADTRAN 6 was developed by Sandia National Laboratories to calculate individual and population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge.

The RADTRAN 6 population risk calculations include both the consequences and probabilities of potential exposure events. The RADTRAN 6 code consequence analyses include the following exposure pathways: cloud shine, ground shine, direct radiation (from loss of shielding), inhalation (from dispersed materials), and resuspension (inhalation of resuspended materials) (SNL 2009). 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 Risks and Consequences of Radioactive Material Transport (RISKIND) computer code (Yuan et al. 1995) was 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 estimate potential radiological consequences and health risks to individuals and the collective population from exposures associated with the transportation of spent nuclear fuel; however, this code is also applicable to transportation of other cargo types, as the code can model complex atmospheric dispersion and estimate radiation doses to MEIs near the accident. Use of the RISKIND computer code as implemented in this *SPD Supplemental EIS* is consistent with direction provided in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002b).

The RISKIND calculations were conducted to supplement the collective risk results calculated with RADTRAN 6. 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?"

E.5.1 Transportation Routes

To assess incident-free and transportation accident impacts, route characteristics were determined for the following offsite shipments that would occur as part of routine operations:

- Pits and associated materials from the Pantex Plant (Pantex) in Texas to the Savannah River Site (SRS) in South Carolina and/or Los Alamos National Laboratory (LANL) in New Mexico
- Plutonium materials from LANL to SRS
- Contact-handled transuranic (CH-TRU) waste from SRS and LANL to the Waste Isolation Pilot Plant (WIPP) in New Mexico
- Unirradiated MOX fuel from SRS to the Browns Ferry Nuclear Plant in Alabama, Sequoyah Nuclear Plant in Tennessee, and a generic commercial nuclear power reactor location in the northwest United States that would envelop impacts related to shipping to other possible commercial nuclear power reactor sites in the country.
- Highly enriched uranium from SRS and LANL to the Y-12 National Security Complex (Y-12) at the Oak Ridge Reservation in Tennessee
- Pieces and parts of pits from SRS to LANL
- Low-level and mixed low-level radioactive waste from SRS and LANL to offsite Federal or commercial disposal facilities; for purposes of analysis in this *SPD Supplemental EIS* it was assumed to be the Nevada National Security Site (NNSS) near Las Vegas, Nevada

- Depleted uranium hexafluoride from the Portsmouth Gaseous Diffusion Plant at Piketon, Ohio, to the AREVA fuel fabrication plant (AREVA) at Richland, Washington[2]
- Depleted uranium oxide and uranyl nitrate hexahydrate from AREVA to SRS[2]
- Hazardous waste from SRS and LANL to an offsite treatment, storage, and disposal facility (nonradiological impacts only)

These sites would constitute the locations where the majority of shipments would be transported.

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 the highway, rail, and waterway routes for transporting radioactive materials within the United States that were used in the analysis. 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 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. The population densities along each route were derived from 2000 Census Bureau data (Johnson and Michelhaugh 2003). State-level U.S. Census data for 2010 (Census 2010) was used in relation to the 2000 census data to project the population densities to 2020 levels.

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 for routes analyzed in this *SPD Supplemental EIS* are summarized in **Table E–1**. Rural, suburban, and urban areas are characterized according to the following breakdown (Johnson and Michelhaugh 2003):

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

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

Analyzed truck routes for offsite shipments of radioactive waste and materials to and from SRS, and from the Portsmouth Gaseous Diffusion Plant to AREVA in Richland, Washington are shown in **Figure E–2**; analyzed truck routes to and from LANL are shown in **Figure E–3**.

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[2] *The transport of depleted uranium is analyzed because it is one of the materials used to produce mixed oxide fuel in the Mixed Oxide Fuel Fabrication Facility (MFFF).*

Table E–1 Offsite Transport Truck Route Characteristics

			Distance Traveled in Zones (kilometers)			***Population Density in Zone [a] (number per square kilometer)***			
Origin	***Destination***	***Nominal Distance (kilometers)***	***Rural***	***Suburban***	***Urban***	***Rural***	***Suburban***	***Urban***	***Number of Affected Persons [b]***
Pantex, TX	SRS	2,184	1,482	621	81	16.7	427.4	2,946.6	844,147
Pantex, TX	LANL	574	526	40	8	8.0	452.1	3,060.7	76,539
SRS	Y-12	633	304	292	37	25.7	481.5	3,154.8	425,642
LANL	Y-12	2,372	1,848	465	59	13.5	370.6	2,866.5	587,874
SRS/LANL [c]	LANL/SRS [c]	2,798	2,015	683	100	14.6	429.2	2,974.9	992,627
SRS	WIPP	2,448	1,732	651	65	17.1	409.7	2,943.4	777,585
LANL	WIPP	597	554	38	5	7.4	378.2	2,582.5	49,414
SRS	NNSS	3,879	3,003	769	107	13.3	436.6	3,007.3	1,113,816
LANL	NNSS	1,250	1,082	132	36	11.4	516.8	4,502.9	387,356
Piketon, OH [d]	Richland, WA [e]	3,768	3,053	648	67	12.9	369.3	2,611.3	726,407
Richland, WA [e]	SRS	4,256	3,253	885	118	13.6	424.9	2,888.7	1,218,892
SRS	Sequoyah Nuclear Plant	508	231	240	37	26.3	523.4	3,161.5	396,561
SRS	Browns Ferry Nuclear Plant	724	389	298	37	24.3	428.1	2,885.8	388,475
SRS	Generic reactor [f]	4,405	3,372	919	114	13.3	419.1	2,897.6	1,216,999

LANL = Los Alamos National Laboratory; NNSS = Nevada National Security Site; OH = Ohio; Pantex = Pantex Plant; SRS = Savannah River Site; TX = Texas; WA = Washington; WIPP = Waste Isolation Pilot Plant; Y-12 = Y-12 National Security Complex.

[a] Population densities have been projected to 2020 using state-level data from the 2010 census (Census 2010) and assuming state population growth rates from 2000 to 2010 continue to 2020.

[b] For offsite shipments, the estimated number of persons residing within 800 meters (0.5 miles) along the transportation route, projected to 2020.

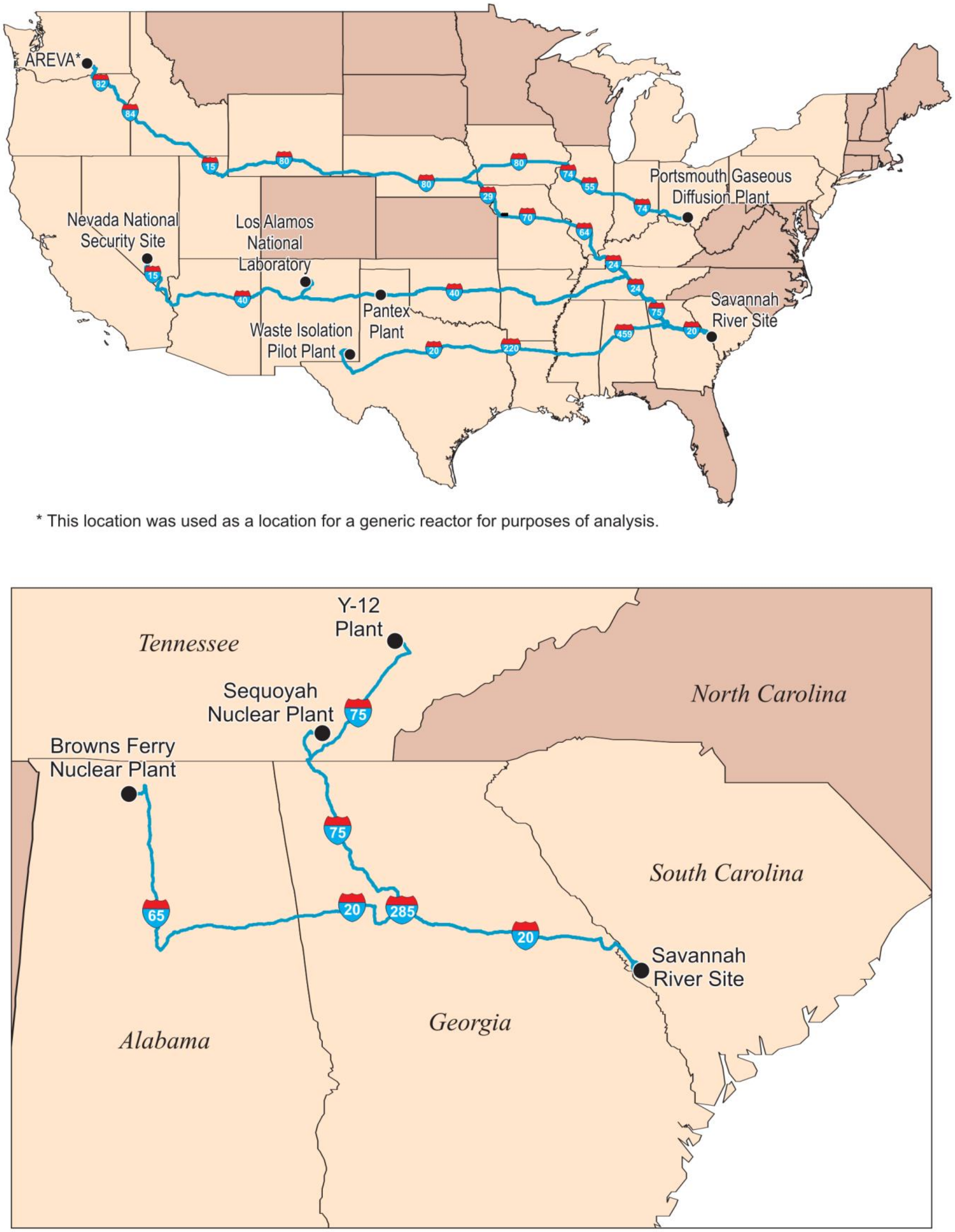
[c] Shipments of plutonium materials would be made from SRS to LANL and from LANL to SRS, depending on the pit disassembly and conversion option.

[d] Shipments of depleted uranium hexafluoride may also be made from the Paducah Gaseous Diffusion Plant at Paducah, Kentucky, but only travel from the Portsmouth Gaseous Diffusion Plant at Piketon, Ohio, was analyzed because this would conservatively estimate the transportation impacts associated with this material.

[e] The AREVA fuel fabrication plant that would convert depleted uranium hexafluoride to depleted uranium oxide is located at Richland, Washington.

[f] For purposes of analysis, it was assumed that the generic commercial nuclear power reactor would be located at the Hanford Reservation, Washington, to maximize the distance traveled in order to envelop impacts related to shipping to other possible commercial nuclear power reactor sites.

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



* This location was used as a location for a generic reactor for purposes of analysis.

Figure E–2 Analyzed National and Regional Truck Routes from Savannah River Site

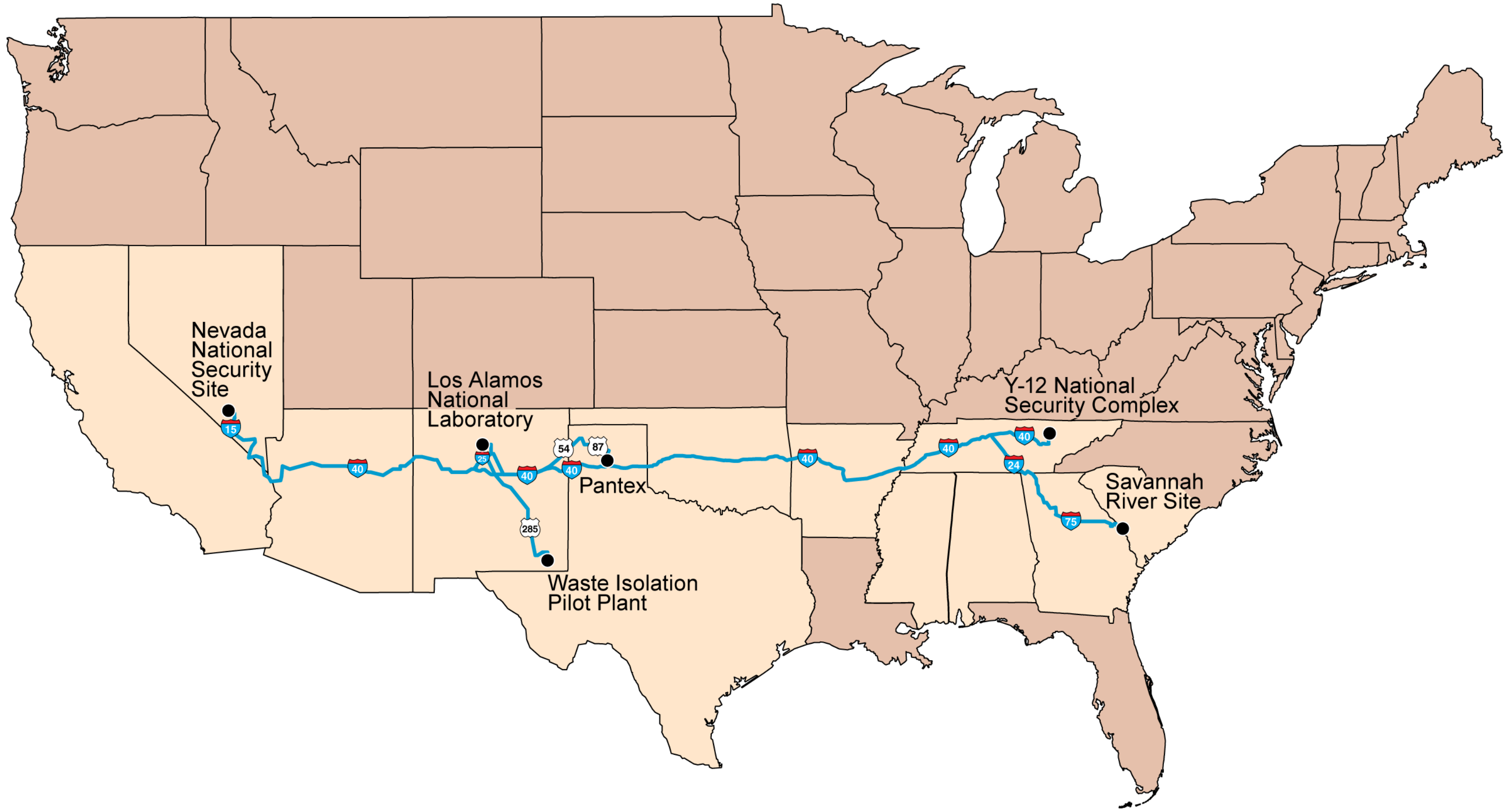


Figure E–3 Analyzed National and Regional Truck Routes from Los Alamos National Laboratory

E.5.2 Radioactive Material Shipments

Transportation of all material and waste types is assumed to occur in certified or certified-equivalent packaging on exclusive-use vehicles. Use of legal-weight heavy combination trucks is assumed in this appendix 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 22,000 kilograms (about 48,000 pounds), based on the Federal gross vehicle weight limit of 36,288 kilograms (80,000 pounds) (23 CFR 658.17). While there are large numbers of multi-trailer 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 2000), for evaluation purposes, the load limit for the legal truck was based on the Federal gross vehicle weight. The width restriction is about 259 centimeters (102 inches) (23 CFR 658.15). Length restrictions vary by state, but are assumed for purposes of analysis to be no more than 14.6 meters (48 feet).

Several types of containers would be used to transport radioactive materials and waste. The various wastes that would be transported under the alternatives in this *SPD Supplemental EIS* include low-level and mixed low-level radioactive waste, CH-TRU waste, demolition and construction debris, and hazardous waste. **Table E–2** lists the types of containers assumed for the analysis along with their volumes and the number of containers in a shipment. A shipment is defined as the amount of waste transported on a single truck.

Table E–2 Material or Waste Type and Associated Container Characteristics [a]

Material or Waste Type	*Container*	*Container Volume (cubic meters) [b]*	*Container Mass (kilograms) [c]*	*Shipment Description*
Mixed low-level radioactive waste	208-liter drum	0.2	399	80 per truck
Low-level radioactive waste	B-25 Box	2.55	4,536	5 per truck
CH-TRU waste	208-liter drum [d]	0.2	399	14 per TRUPACT-II or 7 per HalfPACT; with any combination of 3 TRUPACT-IIs or HalfPACTs per truck
Special nuclear material	Type B package	0.13 to 0.30	183-318	1 to 30 per STA
Unirradiated MOX fuel	Type B package [e]	7.2 to 8.5	2,867 and 4,291	1 transport cask per STA
Fast Flux Test Facility unirradiated fuel	HUFP	9.3	6,350	1 per truck
TRU waste associated with processing non-pit plutonium	Criticality control container	0.2	160	14 per TRUPACT-II
Depleted uranium hexafluoride	30B and 48G, in overpack	2.34 and 4.04	3,751 and 13,800	5 per truck and 1 per truck, respectively
Depleted uranium nitrate hexahydrate	208-liter drum	0.2	399	72 per truck
Construction/demolition debris	Roll-on/Roll-off	15.30	Not applicable	1 per truck
Hazardous waste	208-liter drum	0.2	399	40 per truck

CH-TRU = contact-handled transuranic; HUFP = Hanford Unirradiated Fuel Package; MOX = mixed oxide; STA = secure transportation asset; TRU = transuranic; TRUPACT-II = Transuranic Package Transporter Model 2.

[a] Containers and transport packages identified in this table were used to determine the transportation impacts for purposes of analysis. Specific Type B packages, while not identified in this table, were assumed for specific material or waste types to conduct the analysis. Other containers and transportation packages may be used in addition to, or in lieu of, those shown.

[b] Container exterior volume. To convert from cubic meters to cubic feet, multiply by 35.315; from liters to gallons, by 0.26417.

[c] Filled container maximum mass. Container mass includes the mass of the container shell, its internal packaging, and the materials within. To convert from kilograms to pounds, multiply by 2.2046.

[d] TRU waste consisting of non-pit plutonium would be packaged in pipe overpack containers (POCs), which would be the same size as a 208-liter drum.

[e] Packages for transporting unirradiated MOX fuel assemblies have yet to be designed and certified. For purposes of analysis, a pressurized water reactor package and boiling water reactor package would each contain two fuel assemblies.

In general, the number of shipping containers per shipment was estimated on the basis of the dimensions and weight of the shipping containers, the Transport Index,[3] which is the dose rate at 1 meter (3.3 feet) from the container, and the transport vehicle dimensions and weight limits. The various materials and wastes were assumed to be transported on standard truck semi-trailers in a single stack.

Special nuclear material would be transported using STAs. Special nuclear material transports include plutonium pits, plutonium oxides, enriched uranium, pieces and parts from pit disassembly, and MOX fuel. These shipments would occur to support production of MOX fuel or to accomplish disposition. The numbers of shipments associated with the transport of pits, plutonium oxide, highly enriched uranium, and pieces and parts of pits were determined using up-to-date information regarding the types of transport packages to be used and forecasted generation rates. These materials would be transported in Type B packages. While it is assumed that a specific Type B package would be used for each type of nuclear material being transported for purposes of analysis, more than one particular package design could be used. Use of different Type B packages that are applicable to a particular cargo would not significantly change the impacts presented in this analysis because the designs and shipping configurations of the Type B packages are similar. For unirradiated MOX fuel, the number of shipments is based on two assemblies per transport package, one transport package per shipment; however, alternative shipment configurations are considered, as described in Appendix I, Section I.1.2.5.

Other radioactive materials would be transported by commercial carrier from the Portsmouth Gaseous Diffusion Plant at Piketon, Ohio, to the AREVA fuel fabrication facility at Richland, Washington, and from AREVA to SRS. Depleted uranium hexafluoride would be transported from Piketon, Ohio to Richland Washington, while depleted uranium dioxide and depleted uranium nitrate hexahydrate would be transported from Richland to SRS. Shipments of depleted uranium hexafluoride may also be made from the Paducah Gaseous Diffusion Plant at Paducah, Kentucky, but only travel from the Portsmouth Gaseous Diffusion Plant at Piketon, Ohio, was analyzed because this would conservatively estimate the transportation impacts associated with this material (the total distance traveled and total population exposed along the route from the Paducah Gaseous Diffusion Plant would be less than the distance traveled and population along the route from the Portsmouth Gaseous Diffusion Plant).

For radioactive waste to be transported to a radioactive waste disposal site, it was assumed that the wastes would meet the disposal facility's waste acceptance criteria. For purposes of analysis, it was assumed that some of the low-level radioactive waste generated at the Waste Solidification Building (WSB) (that would not meet waste acceptance criteria for disposal at SRS) would be transported to NNSS for disposal, along with all mixed low-level radioactive waste generated by plutonium disposition activities at SRS. In addition, for purposes of analysis, it was assumed that all low-level radioactive waste and mixed low-level radioactive waste generated at LANL would be transported to NNSS.

Transuranic (TRU) waste would be transported to WIPP for disposal. TRU waste would consist of secondary waste resulting from processing activities and, for the MOX and WIPP Alternatives, of surplus plutonium materials. Under the MOX Alternative, 2 metric tons (2.2 tons) of non-pit plutonium (Fast Flux Test Facility [FFTF] fuel and other non-pit plutonium materials) that is unsuitable for processing at the Mixed Oxide Fuel Fabrication Facility (MFFF) could be transported to WIPP. Under the WIPP Alternative, 7.1 metric tons (7.8 tons) of pit plutonium and 6 metric tons (6.6 tons) of non-pit plutonium could be transported to WIPP. These materials could be packaged in pipe overpack containers (POCs). Besides the use of POCs, other types of containers may be used, as described below:

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

FFTF fuel (for the MOX and WIPP Alternatives): transporting unirradiated FFTF fuel to WIPP in its current transport packaging (Hanford Unirradiated Fuel Package [HUFP])

Other non-pit plutonium (for the MOX and WIPP Alternatives): (a) packaging the plutonium material into criticality control overpacks (CCOs) at a higher concentration and transporting 42 containers per shipment, thereby reducing the number of shipments and disposal volume; or (b) transporting the plutonium materials as currently packaged and stored in the K-Area Complex and placing them in approved Type B packaging for transport to WIPP by STA (direct disposition option).

Pit plutonium (for the WIPP Alternative): (a) disassembling, converting to an oxide and packaging the plutonium material into CCOs at a higher concentration and transporting 42 containers per shipment, thereby reducing the number of shipments and disposal volume; or (b) disassembling and converting to an oxide and placing them in approved Type B packaging for transport to WIPP by STA (included in the direct disposition option).

For the MOX Alternative, any combination of packaging and transport for non-pit plutonium could be used to transport these materials to WIPP. For purposes of analysis, the results presented in Section E.8 include the base case and options for (1) FFTF fuel in HUFPs and other non-pit plutonium in CCOs, and (2) FFTF fuel in HUFPs and direct disposition of other non-pit plutonium.

For the WIPP Alternative, for purposes of analysis, the results presented in Section E.8 include the base case and options for (1) FFTF fuel in HUFPs and pit and non-pit plutonium in CCOs, and (2) FFTF fuel in HUFPs and direct disposition of pit and other non-pit plutonium.

This analytical approach for the MOX and WIPP Alternatives, for the purposes of the transportation analysis, would envelop the potential impacts associated with transport of surplus plutonium materials to WIPP regardless of the packaging and transport method (i.e., commercial carrier versus STA) selected.

E.5.3 Radionuclide Inventories

Radionuclide inventories are used to determine accident risks associated with a release of the radioactive or contaminated cargo. **Table E–3** provides the container radionuclide inventory concentration assumed for low-level and mixed low-level radioactive waste. It is assumed that these two waste types would have the same radioisotopic composition, with the mixed low-level radioactive waste having a hazardous component. The list of radionuclides in these tables is limited to those that would be expected from disassembly and conversion operations. The composition of the waste is the average curie concentration per radioisotope as measured in the year 2010 and received at E-Area, and this composition is assumed to be representative of the low-level and mixed low-level radioactive waste streams generated by surplus plutonium disposition activities.

Table E–3 Low-level and Mixed Low-level Radioactive Waste Radionuclide Concentrations [a]

Nuclide	*Curies per Cubic Meter*
Americium-241	0.000050
Plutonium-238	0.00038
Plutonium-239	0.00011
Plutonium-240	0.000049
Plutonium-241	0.00048
Technetium-99	0.0000052

[a] These isotopes are the primary isotopes to be expected in offsite shipments of low-level and mixed low-level radioactive waste. The concentrations are representative of what historically has been generated at SRS.

Source: SRNS 2012.

For both depleted uranium hexafluoride and depleted uranyl nitrate hexahydrate shipments, the percent concentration of uranium-235 can vary; however, for purposes of analysis, it is assumed that the concentration of uranium-235 is 0.25 percent by mass. For transport of pits from Pantex, Texas, to SRS and LANL; pieces and parts of plutonium pits from SRS to LANL; plutonium oxide from LANL to SRS; and highly enriched uranium from SRS and LANL to Y-12, it was assumed that the contents of one Type B package would be released in the event of an accident.

Table E–4 shows the number of curies per transport package assumed for boiling water reactor (BWR) and pressurized water reactor (PWR) unirradiated MOX fuel.

For the MOX Fuel Alternative and the WIPP Alternative, for which plutonium would be repackaged and sent to WIPP for disposal, for purposes of analysis it was assumed there would be 150 plutonium-239 fissile gram equivalents (FGEs)[4] of non-pit plutonium per POC. A shipment would consist of two TRUPACT-II [Transuranic Package Transporter Model 2] packages and one HalfPACT package. DOE is determining whether the number of FGEs per POC can be increased to reduce both the volume being disposed of and the number of shipments. If the content could be increased, then the plutonium could be packaged in CCOs instead of POCs.[5] If CCOs were used, then it was assumed that a shipment would consist of three TRUPACT II packages, each containing 14 containers. For purposes of analysis, it was assumed that there would be 350 FGEs per CCO.

Table E–4 Radioisotopic Content of Transport Packages Containing Unirradiated Boiling Water Reactor and Pressurized Water Reactor Fuel [a]

Radioisotope	*Pressurized Water Reactor (curies per package)*	*Boiling Water Reactor (curies per package)*
Americium-241	14.90	3.73
Plutonium-238	86.42	21.65
Plutonium-239	2,310.27	578.86
Plutonium-240	511.99	128.28
Plutonium-241	4,364.41	1,093.54
Plutonium-242	0.040	0.0099
Uranium-235	0.0047	0.0019
Uranium-238	0.29	0.12

[a] While specific transport packages have yet to be designed for transporting BWR and PWR unirradiated MOX fuel, it is assumed that the packages would each hold two assemblies.

Source: SRNS 2012.

For TRU waste generated from processing pit plutonium, it was assumed there would be 20 plutonium-239 FGE per drum. For TRU waste generated from processing non-pit plutonium, it was assumed there would be 10 plutonium-239 FGE per drum. A shipment of TRU waste for either of these two cases would consist of three TRUPACT-II packages.

E.6 Incident-free Transportation Risks

E.6.1 Radiological Risk

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

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[4] *Expressing the contents of a shipment in FGE allows the analysis to account for fissile radionuclides that may be present.*

[5] *NRC has issued revised certificates of compliance authorizing use of CCOs for shipment of plutonium within TRUPACT II and HalfPACT transportation packages (NRC 2013). CCOs have been approved for disposal of TRU waste at WIPP.*

Radiological impacts were determined for crew members and the general population during incident-free transportation. For truck shipments, the crew members are the drivers of the shipment vehicle. The general population is composed of the persons residing within 800 meters (0.50 miles) of the truck route (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 (see Chapter 4, Section 4.1.2, of the *SPD Supplemental EIS*). Exposures to inspectors are evaluated and presented separately in this appendix.

Collective doses for the crew and general population were calculated by using the RADTRAN 6 computer code (SNL 2009). 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 (about 6.6 feet) from the outer lateral surfaces of the vehicle (10 CFR 71.47 and 49 CFR 173.441). If a waste container showed a high external dose rate that could exceed this limit, it is categorized as an exclusive use shipment with further transport and dose rate limitations as defined in these regulations, and the cargo would be transported in a Type A or Type B shielded shipping container. The waste container dose rate at 1 meter (3.3 feet) from its surface, or its Transport Index, is dependent on the distribution and quantities of radionuclides, waste density, shielding provided by the packaging, and self-shielding provided by the waste mixture.

Dose rates for packages containing low-level and mixed low-level radioactive waste, highly enriched uranium, pieces and parts of pits, and depleted uranium materials were assigned a dose rate of 2 millirem per hour at 1 meter. The dose rate for packages containing unirradiated MOX fuel (NRC 2005) and plutonium oxide was assumed to be 5 millirem per hour at 1 meter. The dose rate for pits and CH-TRU waste was assumed to be 4 millirem per hour at 1 meter (DOE 1997). In all cases, the maximum external dose rate would be less than or equal to the regulatory limit of 10 millirem per hour at 2 meters from each container.

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 178 for highway-route-controlled quantities of radioactive material within rural, suburban, and urban population zones by using RADTRAN 6 and its default data. In addition, it was assumed for the analysis that, for 10 percent of the time, travel through suburban and urban zones would encounter rush-hour conditions, leading to lower average speed and higher traffic density.

The radiological risks from transporting the waste are 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 rem or person-rem of exposure is used for both the public and workers (DOE 2003b).

E.6.2 Nonradiological Risk

Nonradiological risks, or vehicle-related health risks, resulting from incident-free transport may be associated with the generation of air pollutants by transport vehicles during shipment and are independent of the radioactive nature of the shipment. The health risk associated with these emissions 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 developed, as described in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002b). This analysis was not performed for this *SPD Supplemental EIS* because the results cannot be placed into context by comparison with a standard or measured data. The amounts of vehicle emissions are estimated for each alternative in Chapter 4, Section 4.1.1.

E.6.3 Maximally Exposed Individual Exposure Scenarios

The maximum individual doses for routine offsite transportation were estimated for transportation workers, as well as for members of the general population.

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

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

The hypothetical MEI doses were accumulated over a single year for all transportation shipments. However, for the scenario involving an individual caught in traffic next to a shipping container, the radiological exposures were calculated for only one event because it was considered unlikely that the same individual would be caught in traffic next to all containers for all shipments. For truck shipments, the maximally exposed transportation worker would be a truck crew member who could be a DOE employee or a driver for a commercial carrier. In addition to following DOT requirements, a DOE employee would also need to comply with DOE regulations at 10 CFR Part 835 (“Occupational Radiation Protection”) which limits worker radiation doses to 5 rem per year; however, DOE’s goal is to maintain radiological exposure as low as reasonably achievable. DOE has therefore established the Administrative Control Level of 2 rem per year (DOE-STD-1098-2008). This limit would apply to any non-TRU waste shipment conducted by DOE personnel. Drivers of TRU waste shipments to WIPP have an Administrative Control Level of 1 rem per year (WIPP 2006). Commercial drivers are subject to Occupational Safety and Health Administration regulations, which limits the whole body dose to 5 rem per year (29 CFR 1910.1996(b)), and the DOT requirement of 2 millirem per hour in the truck cab (49 CFR 173.411). Commercial drivers typically do not transport radioactive materials that have high dose rates external to the package; therefore, for purposes of analysis, a maximally exposed driver would not be expected to exceed the DOE Administrative Control Level of 2 rem per year for non-TRU waste shipments. Other workers include inspectors who would inspect the truck and its cargo along the route. One inspector was assumed to be at a distance of 1 meter (3.3 feet) from the cargo for a duration of 1 hour.

E.7 Transportation Accident Risks

E.7.1 Methodology

The offsite transportation accident analysis considers the impact of accidents during the transportation of materials. 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 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 80 kilometers (50 miles) were determined using the RADTRAN 6 computer program (SNL 2009). The RADTRAN 6 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 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).

For accidents where a waste container or the cask shielding was undamaged, population and individual radiation exposure from the waste package was evaluated for the duration that would be needed to recover and resume shipment. The collective dose over all segments of transportation routes was evaluated for an affected population within a distance of 800 meters (0.5 miles) from the accident location. This dose is an external dose, and is approximately inversely proportional to the square of the distance of the affected population from an accident. Any additional dose to those residing beyond 800 meters (0.5 miles) from the accident would be negligible. The dose to an individual (first responder) was calculated assuming that the individual would be located at 2 to 10 meters (6.6 to 33 feet) from the package.

E.7.2 Accident Rates

Whenever material is shipped, the possibility exists of a traffic accident that could result in vehicular damage, injury, or death. Even when drivers are trained in defensive driving and take great care, there is a risk of a traffic accident. DOE and its predecessor agencies have a successful 50-year history of transporting radioactive materials. In the years of moving radioactive and hazardous materials, DOE has not had a single fatality related to transportation of hazardous or radioactive material cargo (DOE 2009).

To calculate 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 its denominator. Accident rates were generally determined for a multi-year 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. No reduction in accident or fatality rates was assumed, even though radioactive material carrier drivers are better trained and have better maintained equipment.

For truck transportation, the rates presented are specifically for heavy combination trucks involved in interstate commerce (Saricks and Tompkins 1999). Heavy combination trucks are rigs composed of a separable tractor unit containing the engine and one to three freight trailers connected to each other. Heavy combination trucks are typically used for radioactive material shipments. Truck accident rates were 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 transportation of radioactive materials and wastes, separate accident rates and accident fatality risks were used for rural, suburban, and urban population zones. The values selected were the state-level accident and fatality rates provided in ANL/ESD/TM-150 (Saricks and Tompkins 1999) under interstate, primary, and total categories for rural, suburban, and urban population zones along the analyzed routes, respectively. The state-level rates were adjusted based on the distance traveled in each population zone in each state to derive a route-specific accident and fatality rate per car-kilometer.

Review of the truck accidents and fatalities reports by the Federal Carrier Safety Administration indicated that state-level accidents and fatalities were underreported. For the years 1994 through 1996, which formed the bases for the analysis in the Saricks and Tompkins report, the review identified that accidents were underreported by about 39 percent and fatalities were underreported by about 36 percent (UMTRI 2003). Therefore, state-level truck accident and fatality rates in the Saricks and Tompkins report were increased by factors of 1.64 and 1.57, respectively, to account for the underreporting.

For transport by STA, the DOE operational experience between 1975 and 1998 was used to determine an accident rate of 2.7×10^{-7} accident per kilometer (4.4×10^{-7} accident per mile) (DOE 2002a). The route-specific commercial truck accident rates were adjusted to reflect the STA accident rate. Accident fatalities for STAs were estimated using the commercial truck transport fatality per accident ratios within each zone.

E.7.3 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, the *Modal Study* (NRC 1987), and the *Reexamination Study* (NRC 2000) for used 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 off site.

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 the *Radioactive Material Transportation Study* for used nuclear fuel shipment 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 used 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 probabilities but high consequences, and those with high probabilities 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 6 computer code. The RADTRAN 6 code sums the product of consequences and probabilities 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.

E.7.4 Atmospheric Conditions

Because it is impossible to predict the specific location of an offsite transportation accident, generic atmospheric conditions were selected for the risk and consequence assessments. On the basis of observations from National Weather Service surface meteorological stations at over 177 locations in the United States, on an annual average, neutral conditions (Pasquill Stability Classes C and D) occur 58.5 percent of the time, and stable (Pasquill Stability Classes E, F, and G) and unstable (Pasquill Stability Classes A and B) conditions occur 33.5 percent and 8 percent of the time, respectively (DOE 2002a). 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 6 is an average weather condition that corresponds to a stability class spread between Class D (for near distance) and Class E (for farther distance).

The accident consequences for the maximum reasonably foreseeable accident (an accident with a likelihood of occurrence greater than 1 in 10 million per year) were assessed for both stable (Class F with a wind speed of 1 meter [3.3 feet] per second) and neutral (Class D with a wind speed of 4 meters [13 feet] per second) atmospheric conditions. The population dose was evaluated under neutral atmospheric conditions and the MEI dose under stable atmospheric conditions. The MEI dose would represent an accident under weather conditions that result in a conservative dose (i.e., a stable weather condition, with minimum diffusion and dilution). The population dose would represent an average weather condition.

E.7.5 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 the waste 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, 2005). The severity categories and corresponding release fractions provided in these documents cover a range of accidents from no impact (zero speed) to impacts with speed in excess of 193 kilometers (120 miles) per hour onto an unyielding surface. Traffic accidents that could occur at the facility would be of minor impact due to lower local speed, with no release potential.

For radioactive wastes 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 *Final West Valley Demonstration Project Waste Management Environmental Impact Statement* (DOE 2003a). For wastes transported in Type A containers (e.g., 208-liter [55-gallon] drums and boxes), the fractions of radioactive material released from the shipping container were based on recommended values from the *Radioactive Material Transportation Study* and DOE Handbook on *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facility* (NRC 1977, DOE 1994). For CH-TRU and remote-handled TRU waste, the release fractions corresponding to the *Radioactive Material Transportation Study* severity categories as adapted in the *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement* were used (DOE 1997).

For those accidents where the waste container or cask shielding were undamaged and no radioactive material was released, it was assumed that it would take 12 hours to recover from the accident and resume shipment for commercial shipments, and 6 hours for STA shipments. During this period, no individual would remain close to the cask. A first responder was assumed to stay at a location 2 to 10 meters (6.6 to 33 feet) from the package for 1 hour (DOE 2002b).

E.7.6 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 attack to be real, and makes all efforts to reduce any vulnerability to this threat.

Nevertheless, DOE has evaluated the impacts of acts of sabotage and terrorism on transportation of used nuclear fuel and high-level radioactive waste shipments (DOE 1996, 2002a). 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 the enveloping analysis for this *SPD Supplemental EIS*. The event was assumed to involve either a truck or rail cask containing light water reactor used 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 rem for events involving a rail- or truck-sized cask, respectively (DOE 2002a). DOE's reassessment of the potential releases in a sabotage event in the *Final 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 2008b) concluded that the consequence of a sabotage event in the *Yucca Mountain EIS* could be overstated by a factor of between 2.5 and 12. Considering a minimum factor of 2 overestimation in the calculated MEI doses, and the fact that any individual dose above 20 rem would lead to a factor of 2 increase in the dose risk conversion factor of 0.0006 LCF per rem, the *Yucca Mountain EIS* MEI dose of 40 to 110 would lead to an increase in risk of fatal cancer to the MEI by 2 to 7 percent. The quantity of radioactive materials transported under all alternatives considered in this *SPD Supplemental EIS* would be less than that considered in the *Yucca Mountain EIS* analysis. Therefore, estimates of risk in the *Yucca Mountain EIS* envelop the risks from an act of sabotage or terrorism involving the radioactive material transported under all alternatives considered in this *SPD Supplemental EIS.*

E.8 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 are presented in **Table E–5**. These factors have been adjusted to reflect the projected population in 2020. 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 waste. 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. LCF risk factors were calculated by multiplying the accident dose risks by a health risk conversion factor of 0.0006 cancer fatalities per person-rem of exposure (DOE 2003b).

For transportation accidents, the risk factors are given for both radiological impacts, in terms of potential LCFs in the exposed population, and nonradiological impacts, in terms of number of traffic fatalities. LCFs represent the number of additional latent fatal cancers among the exposed population. Under accident conditions, the population would be exposed to radiation from released radioactivity if the package were damaged and would receive a direct dose if the package is unbreached. For accidents that had no release, the analysis conservatively assumed that it would take about 12 hours to remove the package and/or commercial vehicle from the accident area (DOE 2002a); 6 hours was assumed for STA shipments. The nonradiological risk factors are nonoccupational traffic fatalities resulting from transportation accidents.

As stated earlier (see Section E.7.3), the accident dose is called “dose risk” because the values incorporate the spectrum of accident severity probabilities and associated consequences (e.g., dose). The accident dose risks are very low because accident severity probabilities (i.e., 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 (i.e., solids) are such that a breach would lead to a nondispersible and mostly noncombustible release. Although persons are residing within an 80-kilometer (50-mile) radius along the transportation route, they are generally quite far from the route. Because RADTRAN 6 uses an assumption of homogeneous population, it would greatly overestimate the actual doses because this assumption theoretically places people directly adjacent to the route where the highest doses would be present.

As indicated in Table E–5, all per-shipment risk factors are less than one. This means that no LCF or traffic fatalities are expected to occur during each transport. For example, the risk factors to truck crew and population for transporting one shipment of pits from Pantex to SRS are given as 3.1×10^{-5} and 3.6×10^{-5} LCFs, respectively. This risk can also be interpreted as meaning that there is a chance of 3 in 100,000 that an additional latent fatal cancer could be experienced among the exposed workers from exposure to radiation during one shipment of this waste. Similarly, there is a chance of 4 in 100,000 that an additional latent fatal cancer could be experienced among the exposed population residing along the transport route due to one shipment. These chances are essentially equivalent to zero risk. It should be noted that the maximum allowable dose rate in the truck cab is less than or equal to 2 millirem per hour.

Table E–5 Risk Factors per Shipment of Radioactive Material and Waste

			Incident-Free				***Accident***	
Material or Wastes	***Origin***	***Transport Destination***	***Crew Dose (person-rem)***	***Crew Risk (LCF)***	***Population Dose (person-rem)***	***Population Risk (LCF)***	***Radiological Risk (LCF)***	***Non-radiological Risk (traffic fatalities)***
Pits [a, b]	Pantex, TX	SRS	0.051	3.1×10^{-5}	0.061	3.6×10^{-5}	1.4×10^{-9}	0.000059
Pits [a, b]	Pantex, TX	LANL	0.013	7.9×10^{-6}	0.018	1.1×10^{-5}	1.4×10^{-10}	0.000017
HEU [a, b]	SRS	Y-12	0.0037	2.2×10^{-6}	0.0057	3.4×10^{-6}	8.6×10^{-11}	0.000011
HEU [a, b]	LANL	Y-12	0.014	8.1×10^{-6}	0.024	1.5×10^{-5}	1.2×10^{-10}	0.000083
Pieces-parts [a, b]	SRS	LANL	0.0028	1.7×10^{-6}	0.0058	3.5×10^{-6}	9.1×10^{-10}	0.000078
Plutonium oxide powder [a, b]	LANL	SRS	0.028	1.7×10^{-5}	0.061	3.7×10^{-5}	7.3×10^{-8}	0.000078
TRU waste in POCs containing surplus plutonium material [c]	SRS	WIPP	0.094	5.7×10^{-5}	0.046	2.7×10^{-5}	8.4×10^{-10}	0.00015
TRU Waste with 10 grams non-pit FGE per drum [d]	SRS	WIPP	0.094	5.7×10^{-5}	0.046	2.7×10^{-5}	8.4×10^{-10}	0.00015
TRU Waste with 20 grams weapons-grade FGE per drum [d]	SRS	WIPP	0.094	5.7×10^{-5}	0.046	2.7×10^{-5}	8.4×10^{-10}	0.00015
TRU Waste with 20 grams weapons-grade FGE per drum [d]	LANL	WIPP	0.023	1.4×10^{-5}	0.012	7.5×10^{-6}	3.0×10^{-11}	0.000021
TRU waste in CCOs containing surplus plutonium material [e]	SRS	WIPP	0.094	5.7×10^{-5}	0.046	2.7×10^{-5}	8.4×10^{-10}	0.00015
Non-pit plutonium direct disposition to WIPP [a, b]	SRS	WIPP	0.073	4.4×10^{-5}	0.16	9.5×10^{-5}	6.5×10^{-8}	0.00015
HUFP [f]	SRS	WIPP	0.013	7.7×10^{-6}	0.026	1.6×10^{-5}	4.3×10^{-8}	0.00015
LLW [g]	SRS	NNSS	0.078	4.7×10^{-5}	0.031	1.9×10^{-5}	2.6×10^{-10}	0.00018
LLW [g]	LANL	NNSS	0.025	1.5×10^{-5}	0.011	6.3×10^{-6}	2.2×10^{-11}	0.000024
MLLW [h]	SRS	NNSS	0.093	5.6×10^{-5}	0.062	3.7×10^{-5}	5.1×10^{-10}	0.00018
MLLW [h]	LANL	NNSS	0.030	1.8×10^{-5}	0.021	1.3×10^{-5}	4.3×10^{-11}	0.000024
DUF$_6$ (48G container)	Piketon, OH [i]	Richland, WA [h]	0.0089	5.3×10^{-6}	0.019	1.2×10^{-5}	1.0×10^{-7}	0.00020
DUF$_6$ (30B container)	Piketon, OH [i]	Richland, WA [h]	0.041	2.5×10^{-5}	0.061	3.7×10^{-5}	8.8×10^{-8}	0.00020
depleted uranium oxide	Richland, WA [j]	SRS	0.10	6.2×10^{-5}	0.061	3.6×10^{-5}	6.3×10^{-7}	0.00023
DUNH	Richland, WA [j]	SRS	0.10	6.2×10^{-5}	0.061	3.6×10^{-5}	3.4×10^{-6}	0.00023
BWR MOX fuel assemblies [k]	SRS	BFN	0.0073	4.4×10^{-6}	0.012	7.2×10^{-6}	1.6×10^{-10}	0.000014
PWR MOX fuel assemblies [k]	SRS	SQN	0.0058	3.5×10^{-6}	0.0080	4.8×10^{-6}	2.1×10^{-10}	0.0000080
BWR MOX fuel assemblies [k]	SRS	Generic Reactor	0.043	2.6×10^{-5}	0.082	4.9×10^{-5}	5.3×10^{-10}	0.000091

BFN = Browns Ferry Nuclear Plant; BWR = boiling water reactor; CCO = criticality control overpack; DUF$_6$ = depleted uranium hexafluoride; DUNH = depleted uranyl nitrate, hexahydrate; FGE = fissile gram equivalent; HEU = highly enriched uranium; HUFP = Hanford Unirradiated Fuel Package; LANL = Los Alamos National Laboratory; LCF = latent cancer fatality; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; MOX = mixed oxide; NNSS = Nevada National Security Site; OH = Ohio; Pantex = Pantex Plant; POC = pipe overpack container; PWR = pressurized water reactor; SQN = Sequoyah Nuclear Plant; SRS = Savannah River Site; TRU = transuranic; TX = Texas; WA = Washington; WIPP = Waste Isolation Pilot Plant; Y-12 = Y-12 National Security complex.

[a] Transported in Type B packages.
[b] Transported by Secure Transportation Assets (STA).
[c] Transported in 208-liter (55-gallon) drums in 2 TRUPACT-IIs and 1 HalfPACT per shipment.
[d] Transported in 208-liter (55-gallon) drums in 3 TRUPACT-IIs per shipment.
[e] Transported in 3 TRUPACT-IIs per shipment.
[f] The HUFP is a Type B package.
[g] Transported in Type A B-25 boxes.
[h] Transported in 208-liter (55-gallon) drums.
[i] Location of the Portsmouth Gaseous Diffusion Plant.
[j] Location of the AREVA fuel fabrication facility.
[k] Assumed to be transported in an as-yet designed transport package that can hold two assemblies.

To provide flexibility for potential disposition of surplus plutonium that cannot be converted into MOX fuel, per-shipment and total transportation impacts for shipment of 6 metric tons (6.6 tons) of plutonium to WIPP for disposal are provided in this appendix. This surplus material is assumed to be packaged in POCs and shipped as CH-TRU waste. For purposes of analysis, it is assumed that a shipment of POCs would consist of 2 TRUPACT II packages and a HalfPACT, with the shipment containing a total of 35 POCs. If CCOs are used, then a shipment would be comprised of 3 TRUPACT II packages containing a total of 42 containers. If the plutonium materials undergo direct disposition to WIPP then the shipment would be transported by STA.

Tables E–6 through E–10 show the risks of transporting radioactive materials and wastes under each alternative. 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 entire period under each alternative and include both construction and operations. The number of shipments for the different waste types was calculated using the estimated waste volumes for each waste type as given in Chapter 4, Section 4.1.4, of the *SPD Supplemental EIS*, the waste container and shipment characteristics provided in Section E.5.2 and Table E–2, and the projected operational duration for each facility (see Appendix B, Table B–2). In each table, the total shipments and associated impacts are provided for three groups: transports including shipments of MOX fuel to TVA reactors, transports including shipments of MOX fuel to a generic reactor, and transports that do not include MOX fuel shipments to reactors.

Comparison of Tables E–6 through E–10 indicates that the WIPP Alternative would have a higher radiological risk to the population during incident-free transportation than the other alternatives due to the greater number of shipments if transport of unirradiated MOX fuel is not considered. For all alternatives, if transport of unirradiated MOX fuel to TVA reactors is considered, the incident-free radiological risks would only slightly increase. If unirradiated MOX fuel is transported to other commercial nuclear power reactors in the United States, then these shipments could comprise about 30 percent of the total incident-free radiological risk to the population from all transports under each alternative, although there likely would not be an LCF.

The MOX Fuel Alternative would have the greatest radiological accident risk among the alternatives because this alternative would require the largest number of shipments of depleted uranium from the Portsmouth Gaseous Diffusion Plant to AREVA, and from AREVA to SRS, assuming no transport of unirradiated MOX fuel. The transport of unirradiated MOX fuel would have about the same radiological accident risk for all of the alternatives.

Nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks, with an estimate of up to 1 fatality if transport of unirradiated MOX fuel to reactors somewhere in the United States is included. Considering the transportation activities analyzed in this *SPD Supplemental EIS* would occur over a 40-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. See Section E.14.5 for further discussion of accident fatality rates.

If HUFPs were used to transport unirradiated FFTF fuel, and CCOs or other approved containers or Type B packaging capable of transporting larger quantities of plutonium material were used to transport plutonium materials to WIPP as TRU waste, there would be a small reduction in transportation risks for incident-free transport for the MOX and WIPP Alternatives despite the number of shipments to WIPP being reduced by more than half. There would be a negligible increase in radiological accident risks in these alternatives.

Table E–6 Risks of Transporting Radioactive Material and Waste – No Action Alternative [a]

				Incident-Free				*Accident*	
				Crew		*Population*			
Route	*Transport Mode*	*Number of Shipments*	*One-way Kilometers Traveled (million)*	*Dose (person-rem)*	*Risk* [b]	*Dose (person-rem)*	*Risk* [b]	*Radiological Risk* [b]	*Nonradiological Risk* [b]
PDCF at F-Area at SRS [c]									
All STA routes	STA	1,100	2.3	52	0.03	62	0.04	1×10^{-6}	0.06
SRS to WIPP	Truck	1,400	3.4	130	0.08	63	0.04	1×10^{-6}	0.2
SRS to NNSS - LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL (2 metric tons [2.2 tons] processing)									
All STA routes	STA	26	0.060	0.58	0.0003	1.3	0.0008	1×10^{-6}	0.002
LANL to WIPP	Truck	15	0.0090	0.34	0.0002	0.19	0.0001	5×10^{-10}	0.0003
LANL to NNSS – LLW	Truck	16	0.020	0.40	0.0002	0.17	0.0001	4×10^{-10}	0.0004
Other Transports									
Portsmouth to AREVA (48G containers)	Truck	140	0.52	1.2	0.0007	2.7	0.002	1×10^{-5}	0.03
Portsmouth to AREVA (30B containers)	Truck	160	0.59	6.4	0.004	9.5	0.006	1×10^{-5}	0.03
AREVA to SRS (DUO_2)	Truck	34	0.15	3.5	0.002	2.1	0.001	2×10^{-5}	0.008
AREVA to SRS (DUNH)	Truck	4	0.017	0.41	0.0002	0.24	0.0001	1×10^{-5}	0.0009
SRS to Generic Reactor [d]	Truck	3,400	15	150	0.09	280	0.2	2×10^{-6}	0.3
Totals									
With fresh MOX Fuel Shipments to a generic reactor [d]	–	6,700	24	380	0.2	430	0.3	0.00007	0.7
Without fresh MOX Fuel Shipments	–	3,300	8.8	230	0.1	150	0.09	0.00007	0.4

AREVA = AREVA fuel fabrication facility; DUNH = depleted uranyl nitrate, hexahydrate; DUO_2 = depleted uranium oxide; LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MOX = mixed oxide; NNSS = Nevada National Security Site; PDCF = Pit Disassembly and Conversion Facility; PF-4 = Plutonium Facility; SRS = Savannah River Site; STA = secure transportation asset; WIPP = Waste Isolation Pilot Plant.

[a] For waste shipments, the totals include construction and operations activities.

[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities. Radiological risk is calculated for one-way travel while nonradiological risk is calculated for two-way travel. Accident dose-risk can be calculated by dividing the risk values by 0.0006 (DOE 2003b). The values are rounded to one non-zero digit.

[c] Includes impacts from MFFF operations.

[d] For purposes of analysis, it was assumed that the generic commercial nuclear power reactor would be located at the Hanford Reservation, Washington, to maximize the distance traveled in order to envelop impacts related to shipping to other possible commercial nuclear power reactor sites. Only shipments of BWR fuel are analyzed because there would be a greater number of shipments to a BWR reactor than a PWR reactor, thus providing a conservative analysis of the distance traveled per alternative that would cover a smaller number of PWR shipments to a generic commercial nuclear power reactor for the same amount of unirradiated MOX fuel, should shipments be made to a PWR.

Note: To convert kilometers to miles, multiply by 0.62137.

Table E–7 Risks of Transporting Radioactive Material and Waste – Immobilization to DWPF Alternative [a]

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
Immobilization Capability									
SRS to WIPP	Truck	550	1.3	52	0.03	25	0.02	5×10^{-7}	0.08
SRS to NNSS – MLLW	Truck	58	0.23	5.4	0.003	3.6	0.002	3×10^{-8}	0.01
PDCF at F-Area at SRS [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,400	3.5	130	0.08	65	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL and MFFF at SRS [d]									
All STA routes	STA	1,700	2.0	28	0.02	47	0.03	3×10^{-5}	0.06
LANL to WIPP	Truck	290	0.17	6.5	0.004	3.6	0.002	9×10^{-9}	0.006
LANL to NNSS – LLW	Truck	320	0.40	7.9	0.005	3.3	0.002	7×10^{-9}	0.008
SRS to WIPP	Truck	1,200	2.9	110	0.07	54	0.03	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL, and H-Canyon/HB-Line and MFFF at SRS [e]									
All STA routes	STA	1,600	2.1	34	0.02	50	0.03	2×10^{-5}	0.06
LANL to WIPP	Truck	240	0.14	5.3	0.003	2.9	0.002	7×10^{-9}	0.005
LANL to NNSS – LLW	Truck	260	0.33	6.5	0.004	2.7	0.002	6×10^{-9}	0.006
SRS to WIPP	Truck	1,200	3.0	120	0.07	56	0.03	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL (2 metric tons [2.2 tons] processing)									
All STA routes	STA	26	0.060	0.58	0.0003	1.3	0.0008	1×10^{-6}	0.002
LANL to WIPP	Truck	15	0.0090	0.34	0.0002	0.19	0.0001	5×10^{-10}	0.0003
LANL to NNSS – LLW	Truck	16	0.020	0.40	0.0002	0.17	0.0001	4×10^{-10}	0.0004
Other Transports									
Portsmouth to AREVA (48G containers)	Truck	140	0.52	1.2	0.0007	2.7	0.002	1×10^{-5}	0.03
Portsmouth to AREVA (30B containers)	Truck	160	0.59	6.4	0.004	9.5	0.006	1×10^{-5}	0.03
AREVA to SRS (DUO_2)	Truck	34	0.15	3.5	0.002	2.1	0.001	2×10^{-5}	0.008
AREVA to SRS (DUNH)	Truck	4	0.017	0.41	0.0002	0.24	0.0001	1×10^{-5}	0.0009
SRS to SQN	STA	430	0.22	2.5	0.001	3.4	0.002	9×10^{-8}	0.003
SRS to BFN	STA	1,700	1.2	12	0.007	20	0.01	3×10^{-7}	0.02
SRS to Generic Reactor [f]	STA	3,400	15	150	0.09	280	0.2	2×10^{-6}	0.3

Route	*Transport Mode*	*Number of Shipments*	*One-way Kilometers Traveled (million)*	*Incident-Free*				*Accident*	
				Crew		*Population*		*Radiological Risk* [b]	*Non-radiological Risk* [b]
				Dose (person-rem)	*Risk* [b]	*Dose (person-rem)*	*Risk* [b]		
Totals									
Immobilization/PDCF with TVA Reactors	-	6,400	12	320	0.2	220	0.1	0.00007	0.6
Immobilization/PDCF with Generic Reactor	-	7,700	26	450	0.3	480	0.3	0.00007	0.8
Immobilization/PF-4/MFFF with TVA Reactors	-	7,000	11	270	0.2	190	0.1	0.00009	0.5
Immobilization/PF-4/MFFF with Generic Reactor	-	8,300	25	400	0.2	440	0.3	0.00009	0.8
Immobilization/PF-4/H-Canyon/ HB-Line/MFFF with TVA Reactors	-	6,900	12	280	0.2	190	0.1	0.00008	0.5
Immobilization/PF-4/H-Canyon/ HB-Line/MFFF with Generic Reactor	-	8,200	25	410	0.2	450	0.3	0.00008	0.8
Immobilization/PDCF	-	4,300	11	300	0.2	200	0.1	0.00007	0.5
Immobilization/PF-4/MFFF	-	4,900	10	250	0.2	160	0.1	0.00009	0.5
Immobilization/PF-4/H-Canyon/ HB-Line/MFFF	-	4,800	10	260	0.2	170	0.1	0.00008	0.5

AREVA = AREVA fuel fabrication facility; BFN = Browns Ferry Nuclear Plant; DUNH = depleted uranyl nitrate, hexahydrate; DUO_2 = depleted uranium oxide; DWPF = Defense Waste Processing Facility; LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fabrication Facility; MLLW = mixed low-level radioactive waste; NNSS = Nevada National Security Site; PDCF = Pit Disassembly Conversion Facility; PF-4 = Plutonium Facility; SQN = Sequoyah Nuclear Plant; SRS = Savannah River Site; STA = secure transportation asset; TVA = Tennessee Valley Authority; WIPP = Waste Isolation Pilot Plant.

[a] For waste shipments, the totals include construction and operations activities.

[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities. Radiological risk is calculated for one-way travel while nonradiological risk is calculated for two-way travel. Accident dose-risk can be calculated by dividing the risk values by 0.0006 (DOE 2003b). The values are rounded to one non-zero digit.

[c] Includes impacts from WSB and MFFF operations.

[d] Includes impacts from further processing at the WSB, metal oxidation at MFFF, and MFFF.

[e] Includes impacts from further processing at the K-Area Complex, H-Canyon/HB-Line, WSB, metal oxidation at MFFF, and MFFF.

[f] For purposes of analysis, it was assumed that the generic commercial nuclear power reactor would be located at the Hanford Reservation, Washington to maximize the distance traveled in order to envelop impacts related to shipping to other possible commercial nuclear power reactor sites. Only shipments of BWR fuel are analyzed because there would be a greater number of shipments to a BWR reactor than a PWR reactor, thus providing a conservative analysis of the distance traveled per alternative that would cover a smaller number of PWR shipments to a generic commercial nuclear power reactor for the same amount of unirradiated MOX fuel, should shipments be made to a PWR.

Note: To convert kilometers to miles, multiply by 0.62137.

Table E–8 Risks of Transporting Radioactive Material and Waste – MOX Fuel Alternative [a]

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population		Radiological Risk [b]	Non-radiological Risk [b]
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]		
PDCF at F-Area at SRS [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,600	3.9	150	0.09	72	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	430	1.7	34	0.02	13	0.008	1×10^{-7}	0.08
PDC [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,600	3.9	150	0.09	73	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	430	1.7	34	0.02	13	0.008	1×10^{-7}	0.08
SRS to NNSS – MLLW	Truck	13	0.050	1.2	0.0007	0.81	0.0005	7×10^{-9}	0.002
PF-4 at LANL and MFFF at SRS [d]									
All STA routes	STA	1,700	2.0	28	0.02	47	0.03	3×10^{-5}	0.06
LANL to WIPP	Truck	290	0.17	6.5	0.004	3.6	0.002	9×10^{-9}	0.006
LANL to NNSS – LLW	Truck	320	0.40	7.9	0.005	3.3	0.002	7×10^{-9}	0.008
SRS to WIPP	Truck	1,400	3.3	130	0.08	62	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	430	1.7	34	0.02	13	0.008	1×10^{-7}	0.08
PF-4 at LANL, and H-Canyon/HB-Line and MFFF at SRS [e]									
All STA routes	STA	1,600	2.1	34	0.02	50	0.03	2×10^{-5}	0.06
LANL to WIPP	Truck	240	0.14	5.3	0.003	2.9	0.002	7×10^{-9}	0.005
LANL to NNSS – LLW	Truck	260	0.33	6.5	0.004	2.7	0.002	6×10^{-9}	0.006
SRS to WIPP	Truck	1,400	3.4	130	0.08	64	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	430	1.7	34	0.02	13	0.008	1×10^{-7}	0.08
H-Canyon/HB-Line to WIPP – 2 Metric Tons (2.2 tons)									
SRS to WIPP, including use of POCs	Truck	500	1.2	47	0.03	23	0.01	4×10^{-7}	0.08
SRS to WIPP, including use of CCOs and HUFPs [f]	Truck	230	0.57	21	0.01	10	0.006	7×10^{-7}	0.04
SRS to WIPP, direct disposition and HUFPs [g]	STA/Truck	32	0.17	1.6	0.0009	3.4	0.002	2×10^{-6}	0.005
PF-4 at LANL (2 metric tons [2.2 tons] processing)									
All STA routes	STA	26	0.060	0.58	0.0003	1.3	0.0008	1×10^{-6}	0.002
LANL to WIPP	Truck	15	0.0090	0.34	0.0002	0.19	0.0001	5×10^{-10}	0.0003
LANL to NNSS – LLW	Truck	16	0.020	0.40	0.0002	0.17	0.0001	4×10^{-10}	0.0004
Other Transports									
Portsmouth to AREVA (48G containers)	Truck	180	0.69	1.6	0.001	3.5	0.002	2×10^{-5}	0.04
Portsmouth to AREVA (30B containers)	Truck	210	0.78	8.5	0.005	13	0.008	2×10^{-5}	0.04
AREVA to SRS (DUO$_2$)	Truck	45	0.19	4.6	0.003	2.7	0.002	3×10^{-5}	0.01
AREVA to SRS (DUNH)	Truck	6	0.026	0.62	0.0004	0.36	0.0002	2×10^{-5}	0.001
SRS to SQN	STA	570	0.29	3.3	0.002	4.6	0.003	1×10^{-7}	0.005
SRS to BFN	STA	2,300	1.7	17	0.01	28	0.02	4×10^{-7}	0.03
SRS to Generic Reactor [h]	STA	4,500	20	190	0.1	370	0.2	2×10^{-6}	0.4

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
Totals									
PDCF with TVA Reactors	-	7,300	13	330	0.2	240	0.1	0.00009	0.6
PDCF/CCO option with TVA Reactors	-	7,000	13	300	0.2	230	0.1	0.00009	0.6
PDCF/direct disposition option with TVA Reactors	-	6,800	12	290	0.2	220	0.1	0.00009	0.5
PDC with TVA Reactors	-	7,300	14	330	0.2	240	0.1	0.00009	0.6
PDC/CCO option with TVA Reactors	-	7,100	13	310	0.2	230	0.1	0.00009	0.6
PDC/direct disposition option with TVA Reactors	-	6,900	12	290	0.2	220	0.1	0.00009	0.5
PF-4/MFFF with TVA Reactors	-	7,900	12	290	0.2	200	0.1	0.0001	0.6
PF-4/MFFF/CCO option with TVA Reactors	-	7,700	12	260	0.2	190	0.1	0.0001	0.5
PF-4/MFFF/direct disposition option with TVA Reactors	-	7,500	11	240	0.1	180	0.1	0.0001	0.5
PF-4/H-Canyon/HB-Line/MFFF with TVA Reactors	-	7,800	13	290	0.2	210	0.1	0.0001	0.6
PF-4/H-Canyon/HB-Line/MFFF/CCO option with TVA Reactors	-	7,500	12	270	0.2	190	0.1	0.0001	0.5
PF-4/H-Canyon/HB-Line/MFFF/direct disposition option with TVA Reactors	-	7,300	11	250	0.1	190	0.1	0.0001	0.5
PDCF with Generic Reactor	-	8,900	31	510	0.3	580	0.3	0.00009	1
PDCF/CCO option with Generic Reactor	-	8,700	31	480	0.3	560	0.3	0.00009	0.9
PDCF/direct disposition option with Generic Reactor	-	8,500	30	460	0.3	560	0.3	0.00009	0.9
PDC with Generic Reactor	-	9,000	31	510	0.3	580	0.3	0.00009	1
PDC/CCO option with Generic Reactor	-	8,700	31	480	0.3	570	0.3	0.00009	0.9
PDC/direct disposition option with Generic Reactor	-	8,500	30	460	0.3	560	0.3	0.00009	0.9
PF-4/MFFF with Generic Reactor	-	9,500	30	460	0.3	540	0.3	0.0001	0.9
PF-4/MFFF/CCO option with Generic Reactor	-	9,300	30	430	0.3	530	0.3	0.0001	0.9
PF-4/MFFF/direct disposition option with Generic Reactor	-	9,100	29	410	0.2	520	0.3	0.0001	0.9
PF-4/H-Canyon/HB-Line/MFFF with Generic Reactor	-	9,400	30	470	0.3	540	0.3	0.0001	0.9
PF-4/H-Canyon/HB-Line/MFFF/CCO option with Generic Reactor	-	9,100	30	440	0.3	530	0.3	0.0001	0.9
PF-4/H-Canyon/HB-Line/MFFF/direct disposition option with Generic Reactor	-	8,900	29	420	0.3	530	0.3	0.0001	0.9
PDCF	-	4,400	11	320	0.2	210	0.1	0.00009	0.6
PDCF/CCO option	-	4,200	11	290	0.2	190	0.1	0.00009	0.5
PDCF/direct disposition option	-	4,000	10	270	0.2	190	0.1	0.00009	0.5
PDC	-	4,500	12	320	0.2	210	0.1	0.00009	0.6
PDC/CCO option	-	4,200	11	290	0.2	200	0.1	0.00009	0.5
PDC/direct disposition option	-	4,000	11	270	0.2	190	0.1	0.00009	0.5
PF-4/MFFF	-	5,000	10	270	0.2	170	0.1	0.0001	0.5
PF-4/MFFF/CCO option	-	4,800	9.8	240	0.1	160	0.1	0.0001	0.5
PF-4/MFFF/direct disposition option	-	4,600	9.4	220	0.1	150	0.09	0.0001	0.4

				Incident-Free				***Accident***	
			One-way	***Crew***		***Population***			
Route	***Transport Mode***	***Number of Shipments***	***Kilometers Traveled (million)***	***Dose (person-rem)***	***Risk*** [b]	***Dose (person-rem)***	***Risk*** [b]	***Radiological Risk*** [b]	***Non-radiological Risk*** [b]
PF-4/H-Canyon/HB-Line/MFFF	-	4,900	11	280	0.2	180	0.1	0.0001	0.5
PF-4/H-Canyon/HB-Line/MFFF/CCO option	-	4,600	9.9	250	0.1	160	0.1	0.0001	0.5
PF-4/H-Canyon/HB-Line/MFFF/direct disposition option	-	4,400	9.5	230	0.1	160	0.1	0.0001	0.5

AREVA = AREVA fuel fabrication facility; BFN = Browns Ferry Nuclear Plant; CCO = criticality control overpack; DUNH = depleted uranyl nitrate, hexahydrate; DUO_2 = depleted uranium oxide; HUFP = Hanford Unirradiated Fuel Package; LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fabrication Facility; MLLW = mixed low-level radioactive waste; MOX = mixed oxide; NNSS = Nevada National Security Site; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly Conversion Facility; PF-4 = Plutonium Facility; POCs = pipe overpack containers; SQN = Sequoyah Nuclear Plant; SRS = Savannah River Site; STA = secure transportation asset; TVA = Tennessee Valley Authority; WIPP = Waste Isolation Pilot Plant.

[a] For waste shipments, the totals include construction and operations activities.

[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities. Radiological risk is calculated for one-way travel while nonradiological risk is calculated for two-way travel. Accident dose-risk can be calculated by dividing the risk values by 0.0006 (DOE 2003b). The values are rounded to one non-zero digit.

[c] Includes impacts from WSB and MFFF operations.

[d] Includes impacts from further processing at the WSB, Metal oxidation at MFFF, and MFFF.

[e] Includes impacts from further processing at the K-Area Complex, H-Canyon/HB-Line, WSB, metal oxidation at MFFF, and MFFF.

[f] For the use of CCOs and HUFPs, non-pit plutonium waste would be packaged in CCOs and not in POCs, reducing the number of shipments. HUFPs would be used to transport FFTF unirradiated fuel instead of repackaging the fuel in POCs. This option is only applicable to the MOX Fuel Alternative and the WIPP Alternative.

[g] For direct disposition, non-pit plutonium waste would remain in their storage containers and be transported in approved Type B packagings and transported via STA. HUFPs would be used to transport FFTF unirradiated fuel instead of repackaging the fuel in POCs.

[h] For purposes of analysis, it was assumed that the generic commercial nuclear power reactor would be located at the Hanford Reservation, Washington to maximize the distance traveled in order to envelop impacts related to shipping to other possible commercial nuclear power reactor sites. Only shipments of BWR fuel are analyzed because there would be a greater number of shipments to a BWR reactor than a PWR reactor, thus providing a conservative analysis of the distance traveled per alternative that would cover a smaller number of PWR shipments to a generic commercial nuclear power reactor for the same amount of unirradiated MOX fuel, should shipments be made to a PWR.

Note: To convert kilometers to miles, multiply by 0.62137.

Table E–9 Risks of Transporting Radioactive Material and Waste – H-Canyon/HB-Line to DWPF Alternative [a]

				Incident-Free				*Accident*	
				Crew		*Population*			
Route	***Transport Mode***	***Number of Shipments***	***One-way Kilometers Traveled (million)***	***Dose (person-rem)***	***Risk [b]***	***Dose (person-rem)***	***Risk [b]***	***Radiological Risk [b]***	***Non-radiological Risk [b]***
PDCF at F-Area at SRS [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,500	3.7	140	0.09	70	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PDC [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,500	3.8	150	0.09	71	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
SRS to NNSS – MLLW	Truck	13	0.050	1.2	0.0007	0.81	0.0005	7×10^{-9}	0.002
PF-4 at LANL and MFFF at SRS [d]									
All STA routes	STA	1,700	2.0	28	0.02	47	0.03	3×10^{-5}	0.06
LANL to WIPP	Truck	290	0.17	6.5	0.004	3.6	0.002	9×10^{-9}	0.006
LANL to NNSS – LLW	Truck	320	0.40	7.9	0.005	3.3	0.002	7×10^{-9}	0.008
SRS to WIPP	Truck	1,300	3.2	120	0.07	59	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL, and H-Canyon/HB-Line and MFFF at SRS [e]									
All STA routes	STA	1,600	2.1	34	0.02	50	0.03	2×10^{-5}	0.06
LANL to WIPP	Truck	240	0.14	5.3	0.003	2.9	0.002	7×10^{-9}	0.005
LANL to NNSS – LLW	Truck	260	0.33	6.5	0.004	2.7	0.002	6×10^{-9}	0.006
SRS to WIPP	Truck	1,300	3.3	130	0.08	62	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL (2 metric tons [2.2 tons] processing)									
All STA routes	STA	26	0.060	0.58	0.0003	1.3	0.0008	1×10^{-6}	0.002
LANL to WIPP	Truck	15	0.0090	0.34	0.0002	0.19	0.0001	5×10^{-10}	0.0003
LANL to NNSS – LLW	Truck	16	0.020	0.40	0.0002	0.17	0.0001	4×10^{-10}	0.0004
H-Canyon/HB-Line and DWPF									
SRS to WIPP	Truck	10	0.025	0.94	0.0006	0.46	0.0003	8×10^{-9}	0.002
Other Transports									
Portsmouth to AREVA (48G containers)	Truck	170	0.63	1.5	0.0009	3.2	0.002	2×10^{-5}	0.03
Portsmouth to AREVA (30B containers)	Truck	190	0.71	7.8	0.005	12	0.007	2×10^{-5}	0.04
AREVA to SRS (DUO_2)	Truck	41	0.17	4.2	0.003	2.5	0.001	3×10^{-5}	0.01
AREVA to SRS (DUNH)	Truck	5	0.021	0.51	0.0003	0.30	0.0002	2×10^{-5}	0.001
SRS to Sequoyah Nuclear Plant	STA	500	0.25	2.9	0.002	4.0	0.002	1×10^{-7}	0.004
SRS to Browns Ferry Nuclear Plant	STA	2,100	1.5	15	0.009	25	0.02	3×10^{-7}	0.03
SRS to Generic Reactor [f]	STA	4,100	18	180	0.1	340	0.2	2×10^{-6}	0.4

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
Totals									
PDCF with TVA Reactors	-	6,400	12	280	0.2	210	0.1	0.00008	0.5
PDC with TVA Reactors	-	6,500	12	280	0.2	210	0.1	0.00008	0.5
PF-4/MFFF with TVA Reactors	-	7,100	11	230	0.1	170	0.1	0.0001	0.5
PF-4/H-Canyon/HB-Line/MFFF with TVA Reactors	-	6,900	11	240	0.1	180	0.1	0.0001	0.5
PDCF with Generic Reactor	-	7,900	28	440	0.3	520	0.3	0.00008	0.8
PDC with Generic Reactor	-	8,000	28	440	0.3	520	0.3	0.00008	0.9
PF-4/MFFF with Generic Reactor	-	8,600	27	390	0.2	480	0.3	0.0001	0.8
PF-4/H-Canyon/HB-Line/MFFF with Generic Reactor	-	8,400	27	400	0.2	490	0.3	0.0001	0.8
PDCF	-	3,800	10	260	0.2	180	0.1	0.00008	0.5
PDC	-	3,900	10	260	0.2	180	0.1	0.00008	0.5
PF-4/MFFF	-	4,500	9.0	210	0.1	140	0.09	0.0001	0.4
PF-4/H-Canyon/HB-Line/MFFF	-	4,300	9.1	220	0.1	150	0.09	0.0001	0.4

AREVA = AREVA fuel fabrication plant; DUNH = depleted uranyl nitrate, hexahydrate; DUO_2 = depleted uranium oxide; DWPF = Defense Waste Processing Facility; LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fabrication Facility; MLLW = mixed low-level radioactive waste; NNSS = Nevada National Security Site; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly Conversion Facility; PF-4 = Plutonium Facility; SRS = Savannah River Site; STA = secure transportation asset; TVA = Tennessee Valley Authority; WIPP = Waste Isolation Pilot Plant.

[a] For waste shipments, the totals include construction and operations activities.

[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities. Radiological risk is calculated for one-way travel while nonradiological risk is calculated for two-way travel. Accident dose-risk can be calculated by dividing the risk values by 0.0006 (DOE 2003b). The values are rounded to one non-zero digit.

[c] Includes impacts from WSB and MFFF operations.

[d] Includes impacts from further processing at the WSB, metal oxidation at MFFF, and MFFF.

[e] Includes impacts from further processing at the K-Area Complex, H-Canyon/HB-Line, WSB, metal oxidation at MFFF, and MFFF.

[f] For purposes of analysis, it was assumed that the generic commercial nuclear power reactor would be located at the Hanford Reservation, Washington to maximize the distance traveled in order to envelop impacts related to shipping to other possible commercial nuclear power reactor sites. Only shipments of BWR fuel are analyzed because there would be a greater number of shipments to a BWR reactor than a PWR reactor, thus providing a conservative analysis of the distance traveled per alternative that would cover a smaller number of PWR shipments to a generic commercial nuclear power reactor for the same amount of unirradiated MOX fuel, should shipments be made to a PWR.

Note: To convert kilometers to miles, multiply by 0.62137.

Table E–10 Risks of Transporting Radioactive Material and Waste – WIPP Alternative [a]

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
PDCF at F-Area at SRS [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,400	3.5	130	0.08	65	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PDC [c]									
All STA routes	STA	1,400	2.9	65	0.04	77	0.05	2×10^{-6}	0.08
SRS to WIPP	Truck	1,400	3.5	140	0.08	66	0.04	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
SRS to NNSS – MLLW	Truck	13	0.050	1.2	0.0007	0.81	0.0005	7×10^{-9}	0.002
PF-4 at LANL and MFFF at SRS [d]									
All STA routes	STA	1,700	2.0	28	0.02	47	0.03	3×10^{-5}	0.06
LANL to WIPP	Truck	290	0. 17	6.5	0.004	3.6	0.002	9×10^{-9}	0.006
LANL to NNSS – LLW	Truck	320	0.40	7.9	0.005	3.3	0.002	7×10^{-9}	0.008
SRS to WIPP	Truck	1,200	2.9	110	0.07	54	0.03	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
PF-4 at LANL, and H-Canyon/HB-Line and MFFF at SRS [e]									
All STA routes	STA	1,600	2.1	34	0.02	50	0.03	2×10^{-5}	0.06
LANL to WIPP	Truck	240	0.14	5.3	0.003	2.9	0.002	7×10^{-9}	0.005
LANL to NNSS – LLW	Truck	260	0.33	6.5	0.004	2.7	0.002	6×10^{-9}	0.006
SRS to WIPP	Truck	1,200	3.0	120	0.07	56	0.03	1×10^{-6}	0.2
SRS to NNSS – LLW	Truck	440	1.7	34	0.02	14	0.008	1×10^{-7}	0.08
H-Canyon/HB-Line to WIPP – 13.1 Metric Tons (14.4 tons)									
SRS to WIPP, including use of POCs	Truck	2,800	6.7	260	0.2	130	0.08	2×10^{-6}	0.4
SRS to WIPP, including use of CCOs and HUFPs [f]	Truck	1,000	2.6	98	0.06	48	0.03	1×10^{-6}	0.2
SRS to WIPP, direct disposition and HUFPs [g]	STA/Truck	180	1.0	13	0.008	21	0.01	8×10^{-6}	0.03
PF-4 at LANL (2 metric tons [2.2 tons] processing)									
All STA routes	STA	26	0.060	0.58	0.0003	1.3	0.0008	1×10^{-6}	0.002
LANL to WIPP	Truck	15	0.0090	0.34	0.0002	0.19	0.0001	5×10^{-10}	0.0003
LANL to NNSS – LLW	Truck	16	0.020	0.40	0.0002	0.17	0.0001	4×10^{-10}	0.0004

Route	***Transport Mode***	***Number of Shipments***	***One-way Kilometers Traveled (million)***	***Incident-Free***				***Accident***	
				Crew		***Population***		***Radiological Risk [b]***	***Non-radiological Risk [b]***
				Dose (person-rem)	***Risk [b]***	***Dose (person-rem)***	***Risk [b]***		
Other Transports									
Portsmouth to AREVA (48G containers)	Truck	140	0.52	1.2	0.0007	2.7	0.002	1×10^{-5}	0.03
Portsmouth to AREVA (30B containers)	Truck	160	0.59	6.4	0.004	9.5	0.006	1×10^{-5}	0.03
AREVA to SRS (DUO_2)	Truck	34	0.15	3.5	0.002	2.1	0.001	2×10^{-5}	0.008
AREVA to SRS (DUNH)	Truck	4	0.017	0.41	0.0002	0.24	0.0001	1×10^{-5}	0.0009
SRS to SQN	STA	500	0.25	2.9	0.002	4.0	0.002	1×10^{-7}	0.004
SRS to BFN	STA	1,700	1.2	12	0.007	20	0.01	3×10^{-7}	0.02
SRS to Generic Reactor [h]	STA	3,400	15	150	0.09	280	0.2	2×10^{-6}	0.3
Totals									
PDCF with TVA Reactors	-	8,500	18	520	0.3	320	0.2	0.00007	0.9
PDCF/CCO option with TVA Reactors	-	6,800	13	360	0.2	240	0.1	0.00007	0.6
PDCF/direct disposition option with TVA Reactors	-	6,000	12	270	0.2	220	0.1	0.00008	0.5
PDC with TVA Reactors	-	8,600	18	520	0.3	320	0.2	0.00007	0.9
PDC/CCO option with TVA Reactors	-	6,900	14	360	0.2	240	0.1	0.00007	0.6
PDC/direct disposition option with TVA Reactors	-	6,000	12	280	0.2	220	0.1	0.00008	0.5
PF-4/MFFF with TVA Reactors	-	9,200	17	470	0.3	290	0.2	0.00009	0.8
PF-4/MFFF/CCO option with TVA Reactors	-	7,500	12	310	0.2	210	0.1	0.00009	0.6
PF-4/MFFF/direct disposition option with TVA Reactors	-	6,600	11	230	0.1	180	0.1	0.0001	0.5
PF-4/H-Canyon/HB-Line/MFFF with TVA Reactors	-	9,000	17	480	0.3	290	0.2	0.00009	0.9
PF-4/H-Canyon/HB-Line/MFFF/CCO option with TVA Reactors	-	7,300	13	320	0.2	210	0.1	0.00008	0.6
PF-4/H-Canyon/HB-Line/MFFF/direct disposition option with TVA Reactors	-	6,500	11	240	0.1	190	0.1	0.00009	0.5
PDCF with Generic Reactor	-	9,800	31	650	0.4	580	0.3	0.00007	1
PDCF/CCO option with Generic Reactor	-	8,100	27	490	0.3	500	0.3	0.00007	0.9
PDCF/direct disposition option with Generic Reactor	-	7,200	25	410	0.2	470	0.3	0.00008	0.8
PDC with Generic Reactor	-	9,800	31	650	0.4	580	0.3	0.00007	1
PDC/CCO option with Generic Reactor	-	8,100	27	490	0.3	500	0.3	0.00007	0.9
PDC/direct disposition option with Generic Reactor	-	7,300	26	410	0.2	470	0.3	0.00008	0.8
PF-4/MFFF with Generic Reactor	-	10,400	30	610	0.4	540	0.3	0.00009	1
PF-4/MFFF/CCO option with Generic Reactor	-	8,700	26	440	0.3	460	0.3	0.00009	0.9
PF-4/MFFF/direct disposition option with Generic Reactor	-	7,900	24	360	0.2	440	0.3	0.0001	0.7
PF-4/H-Canyon/HB-Line/MFFF with Generic Reactor	-	10,300	30	610	0.4	550	0.3	0.00009	1

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled (million)	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
PF-4/H-Canyon/HB-Line/MFFF/CCO option with Generic Reactor	-	8,700	26	450	0.3	470	0.3	0.00009	0.9
PF-4/H-Canyon/HB-Line/MFFF/direct disposition option with Generic Reactor	-	7,700	25	370	0.2	440	0.3	0.00009	0.7
PDCF	-	6,400	16	500	0.3	300	0.2	0.00007	0.9
PDCF/CCO option	-	4,700	12	340	0.2	220	0.1	0.00007	0.6
PDCF/direct disposition option	-	3,800	10	300	0.2	190	0.1	0.00008	0.5
PDC	-	6,400	16	500	0.3	300	0.2	0.00007	0.9
PDC/CCO option	-	4,700	12	340	0.2	220	0.1	0.00007	0.6
PDC/direct disposition option	-	3,900	11	260	0.2	190	0.1	0.00008	0.5
PF-4/MFFF	-	7,000	15	460	0.3	260	0.2	0.00009	0.8
PF-4/MFFF/CCO option	-	5,300	11	290	0.2	180	0.1	0.00009	0.6
PF-4/MFFF/direct disposition option	-	4,500	9.5	210	0.1	160	0.1	0.0001	0.4
PF-4/H-Canyon/HB-Line/MFFF	-	6,900	15	460	0.3	270	0.2	0.00008	0.8
PF-4/H-Canyon/HB-Line/MFFF/CCO option	-	5,200	11	300	0.2	190	0.1	0.00008	0.6
PF-4/H-Canyon/HB-Line/MFFF/direct disposition option	-	4,300	9.6	220	0.1	160	0.1	0.00009	0.4

AREVA = AREVA fuel fabrication facility; BFN = Browns Ferry Nuclear Plant; CCO = criticality control overpack; DUNH = depleted uranyl nitrate, hexahydrate; DUO_2 = depleted uranium oxide; HUFP = Hanford Unirradiated Fuel Package; LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fabrication Facility; MLLW = mixed low-level radioactive waste; NNSS = Nevada National Security Site; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly and Conversion Facility; PF-4 = Plutonium Facility; POC = pipe overpack container; SQN = Sequoyah Nuclear Plant; SRS = Savannah River Site; STA = secure transportation asset; TVA = Tennessee Valley Authority; WIPP = Waste Isolation Pilot Plant.

[a] For waste shipments, the totals include construction and operations activities.

[b] Risk is expressed in terms of LCFs, except for the nonradiological risk, where it refers to the number of traffic accident fatalities. Radiological risk is calculated for one-way travel while nonradiological risk is calculated for two-way travel. Accident dose-risk can be calculated by dividing the risk values by 0.0006 (DOE 2003b). The values are rounded to one non-zero digit.

[c] Includes impacts from WSB and MFFF operations.

[d] Includes impacts from further processing at the WSB, metal oxidation at MFFF, and MFFF.

[e] Includes impacts from further processing at the K-Area Complex, H-Canyon/HB-Line, WSB, metal oxidation at MFFF, and MFFF.

[f] For the use of CCOs and HUFPs, non-pit plutonium waste would be packaged in CCOs and not in POCs, reducing the number of shipments. HUFPs would be used to transport FFTF unirradiated fuel instead of repackaging the fuel in POCs. This option is only applicable to the MOX Fuel Alternative and the WIPP Alternative.

[g] For direct disposition, 6 metric tons (6.6 tons) of non-pit plutonium waste would remain in their storage containers and be transported in approved Type B packagings via STA. HUFPs would be used to transport FFTF unirradiated fuel instead of repackaging the fuel in POCs. In addition, 7.1 metric tons (7.8 tons) of pit plutonium would be disassembled and processed as necessary and repackaged in approved Type B packagings and transported via STA.

[h] For purposes of analysis, it was assumed that the generic commercial nuclear power reactor would be located at the Hanford Reservation, Washington to maximize the distance traveled in order to envelop impacts related to shipping to other possible commercial nuclear power reactor sites. Only shipments of BWR fuel are analyzed because there would be a greater number of shipments to a BWR reactor than a PWR reactor, thus providing a conservative analysis of the distance traveled per alternative that would cover a smaller number of PWR shipments to a generic commercial nuclear power reactor for the same amount of unirradiated MOX fuel, should shipments be made to a PWR.

Note: To convert kilometers to miles, multiply by 0.62137.

For the WIPP Alternative, if 13.1 metric tons (14.4 tons) of pit and non-pit plutonium is repackaged into a Type B container as an oxide and transported to WIPP via STA under direct disposition, then only about 6 percent of the number of shipments would be needed as compared to the transport of POCs under the base case, and about 17 percent of the number of shipments as compared to the transport of CCOs. The corresponding radiological and nonradiological impacts would also be smaller. Under this alternative, all materials to WIPP are assumed to originate from SRS.

Under the PF-4 and MFFF and PF-4, H-Canyon, and MFFF Options under the WIPP Alternative, 7.1 metric tons (7.8 tons) of pit plutonium could be prepared at LANL for potential WIPP disposal, and then shipped directly to WIPP, instead of being transported to SRS for processing with subsequent shipment to WIPP. In this event, there would be fewer shipments of pit plutonium from LANL to SRS, and fewer shipments of TRU waste from SRS to WIPP, but additional shipments of TRU waste from LANL to WIPP. The incident-free and accident impacts associated with shipments from SRS to WIPP would envelop similar shipments from LANL to WIPP because of the longer distances traveled and the larger total population along the route from SRS to WIPP as compared to the route from LANL to WIPP. Therefore, the overall transportation impacts under the WIPP Alternative would be lower if plutonium processing for potential disposal at WIPP occurred at LANL rather than SRS.

If highly enriched uranium metal were transported back to SRS from LANL for processing in the H-Canyon/HB-Line, then the per-shipment risks for this material would be enveloped by the per-shipment risks associated with the transport of pieces/parts from SRS to LANL and the transport of plutonium oxide from LANL to SRS.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for the hypothetical exposure scenarios identified in Section E.6.3. The maximum estimated doses to workers and the public MEIs are presented in **Table E–11**, considering all shipment types. Doses are presented on a per-event basis (person-rem per event, per exposure, or per shipment), because it is generally unlikely that the same person would be exposed to multiple events. For those individuals that could have multiple exposures, the cumulative dose could be calculated. The maximum dose to a crew member is based on the assumption that the same individual is responsible for driving every shipment for the duration of the campaign. Note that the potential exists for larger individual exposures under one-time events of a longer duration. For example, the maximum dose to a person stuck in traffic next to a shipment of low-level radioactive waste for 1 hour is calculated to be 0.015 rem (15 millirem). This is generally considered a one-time event for that individual, although this individual may encounter another exposure of a similar or longer duration in his/her lifetime. An inspector inspecting the conveyance and its cargo would be exposed to a maximum dose rate of 0.018 rem (or 18 millirem) per hour if the inspector stood within 1 meter of the cargo for the duration of the inspection.

A member of the public residing along the route would likely receive multiple exposures from passing shipments. The cumulative dose to this resident is calculated by assuming all shipments pass 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 30 meters (about 98 feet) 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 E–11 for all waste transport types, then the maximum dose to this resident, if all the materials were shipped via this route, would be about 2 millirem, with a risk of developing an LCF of about 1.3×10^{-6}. This dose corresponds to that for truck shipments under the WIPP Alternative, which includes an estimated 9,800 shipments over about a 40-year period.

Table E–11 Estimated Dose to Maximally Exposed Individuals Under Incident-Free Transportation Conditions

Receptor	*Dose to Maximally Exposed Individual*
Workers	
Crew member (truck driver)	2 rem per year [a]
Inspector	0.019 rem per event per hour of inspection
Public	
Resident (along the truck route)	2.6×10^{-7} rem per event
Person in traffic congestion	0.0081 rem per event per one hour stop
Person at a rest stop/gas station	0.00024 rem per event per hour of stop
Gas station attendant	0.00053 rem per event

[a] In addition to complying with DOT requirements, a DOE employee would also need to comply with 10 CFR Part 835 that limits worker radiation doses to 5 rem per year; however, DOE's goal is to maintain radiological exposure as low as reasonably achievable. DOE has therefore established the Administrative Control Level of 2 rem per year (DOE-STD-1098-2008). Based on the number of commercial shipments and the total crew dose to 2 drivers in Tables E–6 to E–10, a commercial driver would not exceed this administrative control limit; therefore, the administrative control limit is reflected in Table E–11 for the maximally exposed truck crew member.

The accident risk assessment and the impacts shown in Tables E–6 through E–10 takes into account the entire spectrum of potential accidents, from the fender-bender to the extremely severe. 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 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 100 meters (330 feet) 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 assumed.
- The population is assumed to have a uniform density to a radius 80 kilometers (50 miles) and to be 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 assumed. Because the consequence is proportional to the population density, the accident is assumed to occur in an urban[6] area with the highest density (see Table E–1).
- The type and number of containers involved in the accident is listed in Table E–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 E–12 provides the estimated dose and potential LCFs that could result for an individual and population from a maximum foreseeable truck transportation accident with the highest consequences under each alternative. (Only those accidents with a probability greater than 1×10^{-7} per year

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[6] *If the likelihood of an accident in an urban area is less than 1-in-10 million per year, then the accident is evaluated for a suburban area.*

are analyzed.) The accident is assumed to involve a severe impact (collision) in conjunction with a long fire duration. The highest consequences for the maximum foreseeable accident based on population dose are from accidents occurring in a suburban area involving the transport of plutonium oxide powder from LANL to SRS.

Table E–12 Estimated Dose to the Population and to Maximally Exposed Individuals Under the Maximum Reasonably Foreseeable Accident

					Population [b]		***MEI*** [c]	
Transport Mode	***Material or Waste in the Accident With the Highest Consequences***	***Applicable Alternatives***	***Range of Likelihood of the Accident (per year)*** [a]	***Population Zone*** [a]	***Dose (person-rem)***	***LCF***	***Dose (rem)***	***LCF***
STA transport from Pantex	Pits	All	5.6×10^{-7} to 7.0×10^{-7}	suburban	83	0.05	0.070	4×10^{-5}
Truck transport to WIPP	Pit weapons-grade TRU waste in a TRUPACT II	All	3.3×10^{-7} to 3.4×10^{-7}	urban	8.7	0.005	0.0011	6×10^{-7}
Truck transport to WIPP	Non-pit KIS TRU waste in a TRUPACT II	H-Canyon/ HB-Line to DWPF, WIPP [d]	2.2×10^{-8} to 2.0×10^{-7}	suburban	1.6	0.001	0.0014	9×10^{-7}
Truck transport to WIPP	Processed non-pit plutonium as TRU waste in POCs	MOX Fuel, WIPP	2.2×10^{-7} to 1.0×10^{-6}	urban	180	0.1	0.022	1×10^{-5}
Truck transport to Browns Ferry	BWR MOX Fuel	All except No Action [e]	4.6×10^{-7} to 5.4×10^{-7}	suburban	4.1	0.002	0.0035	2×10^{-6}
Truck transport to Generic Reactors	BWR MOX Fuel	All	2.8×10^{-6} to 3.3×10^{-6}	suburban	4.0	0.002	0.0035	2×10^{-6}
Truck transport to NNSS	LLW in B-25s	All	4.3×10^{-7} to 5.0×10^{-7}	suburban	0.015	9×10^{-6}	0.000012	7×10^{-9}
Truck transport to AREVA	Depleted uranium hexafluoride in 30B containers	All	2.1×10^{-7} to 2.4×10^{-7}	suburban	620	0.4	0.64	4×10^{-4}
Truck transport to AREVA	Depleted uranium hexafluoride in 48G containers	All	1.8×10^{-7} to 2.1×10^{-7}	suburban	750	0.4	0.78	5×10^{-4}
Truck transport to WIPP	Processed non-pit TRU waste in criticality control containers	MOX Fuel, WIPP	7.9×10^{-8} to 3.7×10^{-7}	urban	420	0.3	0.051	3×10^{-5}
STA transport to SRS	Plutonium oxide powder in a Type B package	All except No Action [e]	4.3×10^{-8} to 2.0×10^{-7}	suburban	6,300	4	4.3	3×10^{-3}
STA transport to WIPP	Non-pit TRU waste via direct disposition	WIPP [d]	1.1×10^{-6}	suburban	1,890	3	1.4	9×10^{-4}

AREVA = AREVA fuel fabrication facility; BWR = boiling water reactor; DWPF = Defense Waste Processing Facility; KIS = K-Area Interim Surveillance; LCF = latent cancer fatality; LLW = low-level radioactive waste; MEI = maximally exposed individual; MOX = mixed oxide fuel; NNSS = Nevada National Security Site; Pantex = Pantex Plant; POC = pipe overpack container; SRS = Savannah River Site; STA = safeguards transporter; TRU = transuranic; TRUPACT-II = Transuranic Package Transporter Model 2; WIPP = Waste Isolation Pilot Plant.

[a] The likelihood shown is the range of likelihood estimated among the alternatives given the number of shipments over a specific time period. If the likelihood of an accident is equal to or greater than 1 in 10 million per year for both suburban and urban population zones, then the consequences are provided for the urban population zone.

[b] Population extends at a uniform density to a radius of 80 kilometers (50 miles). The weather condition was assumed to be Pasquill Stability Class D with a wind speed of 4 meters per second (8.8 miles per hour).

[c] The MEI is assumed to be 100 meters (330 feet) 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 1 meter per second (2.2 miles per hour).

[d] While these shipments would occur under the MOX Fuel Alternative, the likelihood of an accident in a suburban area would be less than 1 in 10 million per year.

[e] For the No Action Alternative, the likelihood of an accident in a suburban area would be less than 1 in 10 million per year.

E.9 Impact of Hazardous Waste and Construction and Operational Material Transport

This section evaluates the impacts of transporting hazardous wastes, as well as materials required to construct new facilities. For construction materials, it was assumed that these materials would be transported 50 kilometers (31 miles) one way. Hazardous wastes were assumed to be transported about 2,000 kilometers (1,240 miles). The truck accident and fatality rates that were assumed for construction materials were 7.69 accidents per 10 million truck-kilometers travelled and 4.08 fatalities per 100 million truck-kilometers travelled (Saricks and Tompkins 1999; UMTRI 2003), which is reflective of transportation in South Carolina. The truck accident and fatality rates that were assumed for transport of hazardous materials were 5.77 accidents per 10 million truck-kilometers travelled and 2.34 fatalities per 100 million truck-kilometers travelled (Saricks and Tompkins 1999; UMTRI 2003), which is reflective of the national mean. **Tables E–13** and **E–14** summarize the impacts in terms of total number of kilometers, accidents, and fatalities for all alternatives. The results indicate that there would be a smaller risk of traffic accidents and fatalities for the disassembly and conversion options that maximize use of current facilities.

Table E–13 Estimated Impacts of Construction Material Transport

Alternative	*Disassembly and Conversion Option*	*Number of Shipments*	*Total Distance Traveled (kilometers; two-way)*	*Number of Accidents*	*Number of Fatalities*
No Action	PDCF	42,000	4,200,000	3.2	0.2
Immobilization to DWPF	PDCF	43,000	4,300,000	3.3	0.2
	PF-4 and MFFF [a]	1,200	120,000	0.09	0.005
	PF-4, H-Canyon/HB-Line, and MFFF [b]	1,200	120,000	0.09	0.005
MOX Fuel	PDCF	42,000	4,200,000	3.2	0.2
	PDC	43,000	4,300,000	3.3	0.2
	PF-4 and MFFF [a]	0	0	0	0
	PF-4, H-Canyon/HB-Line, and MFFF [b]	0	0	0	0
H-Canyon/ HB-Line to DWPF	PDCF	42,000	4,200,000	3.2	0.2
	PDC	43,000	4,300,000	3.3	0.2
	PF-4 and MFFF [a]	0	0	0	0
	PF-4, H-Canyon/HB-Line, and MFFF [b]	0	0	0	0
WIPP	PDCF	42,000	4,200,000	3.2	0.2
	PDC	43,000	4,300,000	3.3	0.2
	PF-4 and MFFF [a]	0	0	0	0
	PF-4, H-Canyon/HB-Line, and MFFF [b]	0	0	0	0

DWPF = Defense Waste Processing Facility; MFFF = Mixed Oxide Fabrication Facility; MOX = mixed oxide; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly and Conversion Facility; PF-4 = Plutonium Facility; WIPP = Waste Isolation Pilot Plant.

[a] Under this option, pits would be disassembled at PF-4 at LANL. Pits disassembled at LANL would be converted to an oxide at LANL or using H-Canyon/HB-Line or oxidation furnaces installed at MFFF at SRS.

[b] Under this option, pits could be disassembled at PF-4 at LANL or at the K-Area Complex at SRS. Pits disassembled at LANL would be converted to an oxide at LANL or using H-Canyon/HB-Line or oxidation furnaces installed at MFFF at SRS. Pits disassembled at the K-Area Complex at SRS would be converted to an oxide at H-Canyon/HB-Line.

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

Table E–14 Estimated Impacts of Hazardous Waste Transport

Alternative	*Disassembly and Conversion Option*	*Number of Shipments*	*Total Distance Traveled (kilometers; two-way)*	*Number of Accidents*	*Number of Fatalities*
No Action	PDCF	11	44,000	0.026	0.001
Immobilization to DWPF	PDCF	66	270,000	0.15	0.006
	PF-4 and MFFF [a]	61	250,000	0.14	0.006
	PF-4, H-Canyon/HB-Line, and MFFF [b]	67	270,000	0.16	0.006
MOX Fuel	PDCF	9	40,000	0.021	0.0009
	PDC	440	1,800,000	1.0	0.04
	PF-4 and MFFF [a]	4	16,000	0.009	0.0004
	PF-4, H-Canyon/HB-Line, and MFFF [b]	5	20,000	0.012	0.0005
H-Canyon/ HB-Line to DWPF	PDCF	9	36,000	0.021	0.0009
	PDC	450	1,800,000	1.0	0.04
	PF-4 and MFFF [a]	4	16,000	0.009	0.0004
	PF-4, H-Canyon/HB-Line, and MFFF [b]	5	20,000	0.012	0.0005
WIPP	PDCF	9	36,000	0.021	0.0009
	PDC	450	1,800,000	1.0	0.04
	PF-4 and MFFF [a]	4	16,000	0.009	0.0004
	PF-4, H-Canyon/HB-Line, and MFFF [b]	4	16,000	0.009	0.0004

DWPF = Defense Waste Processing Facility; MFFF = Mixed Oxide Fabrication Facility; MOX = mixed oxide; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly and Conversion Facility; PF-4 = Plutonium Facility; WIPP = Waste Isolation Pilot Plant.

[a] Under this option, pits would be disassembled at PF-4 at LANL. Pits disassembled at LANL would be converted to an oxide at LANL or using H-Canyon/HB-Line or oxidation furnaces installed at MFFF at SRS.

[b] Under this option, pits could be disassembled at PF-4 at LANL or at the K-Area Complex at SRS. Pits disassembled at LANL would be converted to an oxide at LANL or using H-Canyon/HB-Line or oxidation furnaces installed at MFFF at SRS. Pits disassembled at the K-Area Complex at SRS would be converted to an oxide at H-Canyon/HB-Line.

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

E.10 Chemical Impacts

The chemical nature of depleted uranium and other hazardous chemicals does not pose cargo-related risks to humans during routine transportation-related operations. Transportation operations are generally well regulated with respect to packaging, such that small spills or seepages during routine transport are kept to a minimum and do not result in exposures. Potential cargo-related health risks to humans can occur only if the integrity of a container is compromised during an accident (i.e., if a container is breached). Under such conditions, some chemicals may cause an immediate health threat to exposed individuals, primarily through inhalation exposure (DOE 2004).

The risks from exposure to hazardous chemicals during transportation-related accidents can be either acute (resulting in immediate injury or fatality) or latent (resulting in cancer that would present itself after a latency period of several years). Acute health impacts were evaluated for the accidental release of uranium hexafluoride and uranium dioxide in the *Environmental Impact Statement on the Construction and Operation of a Proposed Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina* (NRC 2005:C-7). Latent health impacts from accidental chemical releases were not evaluated because these two chemicals are not considered carcinogenic. The primary exposure route of concern with respect to accidental release of hazardous chemicals would be inhalation. The results indicated that the potential for irreversible adverse effects from chemical exposures would be about 1 in 830 million as a result of MFFF operations. These results would be comparable to the impacts associated with transportation activities in this *SPD Supplemental EIS* because the transport of depleted uranium hexafluoride and uranium dioxide would only be associated with MFFF operations.

Depleted uranyl nitrate hexahydrate (DUNH) would be transported in the form of a liquid in drums from AREVA at Richland, Washington, to SRS for use in MFFF operations. DUNH contains nitric acid and is noncombustible and mildly chemically toxic. DUNH will accelerate the burning of other combustible materials if concentrated or if the water in the liquid evaporates. If involved in a fire, DUNH produces toxic oxides of nitrogen and large quantities of DUNH may explode (ChemicalBook 2010); however, this hazard would be minimized in activities related to the *SPD Supplemental EIS* because this chemical would be transported in small quantities in drums.

E.11 Onsite Transports

Onsite shipment of radioactive materials and wastes at SRS would not affect any members of the public because roads between SRS processing areas are closed to the public; therefore, shipments would only affect onsite workers. Shipments of TRU waste and low-level and mixed low-level radioactive waste to E-Area are currently conducted as part of site operations with no discernable impact on noninvolved workers. The transport of radioactive materials and wastes under the alternatives is not expected to significantly increase the risk to these workers. As shown in this appendix, the risks from incident-free transport of radioactive waste and materials off site over long distances (hundreds to thousands of kilometers) are very small; therefore, the risks from transporting radioactive waste and materials on site, where distances would be less than 20 kilometers (12 miles) and sometimes less than 5 kilometers (3 miles), would be even smaller. For NNSA STA shipments, onsite roads would be closed during transport, further limiting the risk of noninvolved worker exposure. All involved workers (drivers and escorts) are monitored, and the maximum annual dose to a transportation worker would be administratively limited to 2 rem (10 CFR Part 835, DOE-STD-1098-2008). The potential for a trained radiation worker to develop a fatal latent cancer from the maximum annual exposure is 0.0012 LCFs; therefore, an individual transportation worker is not expected to develop a lifetime latent fatal cancer from exposure during these activities. Impacts associated with accidents during onsite transport of radioactive materials and wastes would be less than the impacts assessed for the bounding accident analyses for the plutonium disposition facilities (see Section 4.1.2.2), as well as the impacts for offsite transports, because of the much shorter distances traveled, onsite security measures, and lower onsite vehicle speeds. Because of these reasons, the impacts of onsite transport of radioactive materials and wastes are not analyzed further in this *SPD Supplemental EIS*.

The number of onsite shipments of materials and wastes is incorporated into the air quality impacts analysis described in Chapter 4, Section 4.1.1. Onsite shipments include transports of pits, metal, and oxides between the storage facility at the K-Area Complex and the proposed Pit Disassembly and Conversion Facility (PDCF), Pit Disassembly and Conversion Project (PDC), H-Canyon/HB-Line, and MFFF. SRS resources are assumed to be used to ship materials to MFFF and to and from the Analytical Laboratories in F- and H-Areas. Material is shipped in several possible types of Type B transportation packages loaded onto shipping pallets called either cargo pallet assemblies (CPAs) or Cargo Restraint Transporters (CRTs).

Non-pit plutonium material is packaged in a Type B package for storage. The Type B packages are stored in K-Area storage vaults until enough packages are accumulated for shipment to MFFF. It is assumed that each MFFF shipment consists of 25 packages. Pit disassembly byproducts (pieces/parts) are transported back from the disassembly facility to the K-Area Complex for storage until enough packages are accumulated for shipment off site (assumed to be sent to LANL). It is assumed that byproducts are shipped every time 16 packages are accumulated. Highly enriched uranium oxide is placed in a Type B package and transported to the K-Area Complex for storage until enough containers are accumulated for shipment off site to the Highly Enriched Uranium Disposition Program (assumed to be at Y-12). This analysis assumes that each highly enriched uranium shipment consists of 25 containers.

In addition to transport of plutonium, pit disassembly and conversion would produce radioactive wastes that would be transported on site to E-Area for further management (the majority of low-level radioactive waste would be disposed of at E-Area, while TRU waste, mixed low-level radioactive waste, and hazardous waste would be stored at E-Area prior to offsite transport). Nonradioactive hazardous waste would be disposed of at the Three Rivers Regional Landfill, located at SRS. TRU waste, mixed low-level radioactive waste, and hazardous waste are assumed to be transported in 55-gallon drums, with 20 drums per onsite shipment. Low-level radioactive waste is assumed to be transported in B-25 boxes, with 5 boxes per onsite shipment. Solid nonhazardous waste is assumed to be transported in roll-off containers, with 1 container per onsite shipment. The number of offsite shipments is presented in Tables E–6 through E–10.

The following subsections summarize the number of onsite shipments of materials and wastes.

E.11.1 Onsite Shipments Related to Pit Disassembly and Conversion Options

The number of onsite shipments of solid waste related to construction and operation impacts from Disassembly and Conversion Options are presented for all applicable facilities in **Tables E–15** and **E–16**, while the number of shipments associated with transporting plutonium materials are presented below.

Table E–15 Average Annual Number of Onsite Waste Shipments Due to Construction and Modifications from Disassembly and Conversion Options [a]

Facility	*TRU Waste to E-Area*	*LLW to E-Area*	*MLLW to E-Area*	*Hazardous Waste to E-Area*	*Solid Nonhazardous Waste to Three Rivers Landfill*
PDCF	0	0	0	2	8
PDC	1	85	5	160	41
Metal oxidation at MFFF	0	0	0	0	0
H-Canyon/HB-Line	1	1	0	0	0
PF-4 to TA-54, LANL [b]	1	1	1	0	0 [c]

LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fuel Fabrication Facility; MLLW = mixed low-level radioactive waste; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly and Conversion Facility; PF-4 = Plutonium Facility; TA = technical area; TRU = transuranic.

[a] TRU waste, MLLW, and hazardous waste are assumed to be transported in 55-gallon drums, with 20 drums per shipment. LLW is assumed to be transported in B-25 boxes, with 5 boxes per shipment. Solid nonhazardous waste is assumed to be transported in a roll-off container, with 1 container per shipment.

[b] Radioactive wastes would be transported to TA-54, not to E-Area at SRS. Solid nonhazardous would be transported off site to a solid waste landfill located near LANL.

[c] Nonhazardous waste is not tracked at the facility level. Nonhazardous waste would be transported off site from the generating facility.

Table E–16 Pit Disassembly and Conversion Facility Average Annual Number of Onsite Waste Shipments Due to Operations from Disassembly and Conversion Options [a]

Facility	*TRU Waste to E-Area*	*LLW to E-Area*	*MLLW to E-Area*	*Hazardous Waste to E-Area*	*Solid Nonhazardous Waste to Three Rivers Landfill*
PDCF	44	77	0	0	130
PDC	44	77	0	0	130
Metal Oxidation at MFFF	2	1	0	0	0
H-Canyon/HB-Line	4	8	0	0	0
PF-4 to TA-54, LANL [b]	27	14	1	0	0

LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fuel Fabrication Facility; MLLW = mixed low-level radioactive waste; PDC = Pit Disassembly and Conversion Project; PDCF = Pit Disassembly and Conversion Facility; PF-4 = Plutonium Facility; TA = technical area; TRU = transuranic.

[a] TRU waste, MLLW, and hazardous waste are assumed to be transported in 55-gallon drums, with 20 drums per shipment. LLW is assumed to be transported in B-25 boxes, with 5 boxes per shipment. Solid nonhazardous waste is assumed to be transported in a roll-off container, with 1 container per shipment.

[b] TRU wastes would be transported to TA-54 and not to E-Area at SRS. All other waste streams would be transported off site for disposition. Shipment values are related to action alternatives.

PDCF in F-Area at SRS

Construction—PDCF would be constructed over an 11-year period. Construction of PDCF would generate hazardous waste and solid nonhazardous waste. Based on Table E–15, there would be no radioactive waste shipments and the majority of the waste would be nonhazardous (sanitary) because the facility would be constructed on a new site.

Operations—The materials processed in PDCF at F-Area include plutonium pits, metals, and certain alternate feedstock materials. All of these materials are stored within Type B packages. The plutonium would be transported to PDCF, where it would be converted to oxide, packaged in Type B packages, and transported back to the K-Area Complex for storage. Byproducts and highly enriched uranium would also be returned to the K-Area Complex prior to being transported off site for disposition. The resulting plutonium oxide, including alternate feedstock materials that do not require processing in PDCF, would then be transported back to MFFF in F-Area.

There would be a total of about 280 to 350 shipments of plutonium from the K-Area Complex to PDCF in F-Area for disassembly and conversion, depending on the alternative. About the same number of plutonium oxide shipments would be made back to the K-Area Complex to store the plutonium oxide prior to shipment to MFFF, along with about 25 to 30 shipments of byproducts and 130 to 170 shipments of highly enriched uranium. About 340 to 410 shipments would subsequently be made from the K-Area Complex to MFFF in F-Area (including all alternate feedstock materials).

Based on Table E–16, there would be annual onsite shipments of TRU waste and low-level radioactive waste to E-Area, as well as nonhazardous waste to the Three Rivers Landfill.

PDC

Construction—PDC modifications would be accomplished over a 12-year period. Modification of PDC would generate low-level radioactive waste, mixed low-level radioactive waste, and hazardous waste, which would be sent to E-Area, as well as solid nonhazardous waste, which would be transported to the Three Rivers Landfill.

Operations—Modification and operation of a new PDC at K-Area would only occur under the MOX Fuel Alternative, H-Canyon/HB-Line to DWPF Alternative, and WIPP Alternative. The plutonium pits and metals would be transported to PDC for conversion. There would be no intrasite shipments required between PDC and K-Area storage because these facilities would be collocated within K-Area. There would be about 410 plutonium oxide shipments made from K-Area storage to MFFF in F-Area (including alternate feedstock materials).

Based on Table E–16, there would be annual onsite shipments of TRU waste, low-level radioactive waste, and nonhazardous waste to the Three Rivers Landfill. Because PDC in K-Area would operate in a similar manner as PDCF in F-Area, it can be assumed that the number of waste shipments would be the same regardless of which facility is used.

Pit Disassembly at LANL TA-55 Area (PF-4)

Construction—Modification activities at the Plutonium Facility (PF-4) would be minor in nature and would cause some transports on site at LANL of TRU, low-level radioactive, and mixed low-level radioactive waste to Technical Area-54 (TA-54) for storage and eventual shipment off site.

Operations—Pit disassembly at LANL's PF-4 is another option that could occur under all alternatives, except the No Action Alternative. There would be no onsite shipments of plutonium materials at LANL. Tables E–6 through E–10 show the number of intersite transports that would occur from Pantex to LANL, LANL to SRS, and LANL to Y-12. It is assumed that plutonium shipments from LANL would arrive at the K-Area Complex for storage prior to transport to MFFF. The same number of transports from K-Area storage to MFFF would occur under this option as presented for the PDC Option discussed above.

Onsite waste shipments at LANL would be limited to TRU waste, low-level radioactive waste, and mixed low-level radioactive waste. The number of onsite TRU waste shipments at LANL would be about a third of the number of the same shipments that would occur at SRS if PDC or PDCF were used.

Pit Disassembly at LANL PF-4 in Combination with H-Canyon/HB-Line at SRS and MFFF at SRS

Construction—The number of onsite shipments at LANL related to modifying PF-4 would be the same as that identified under "Pit Disassembly at LANL TA-55 Area (PF-4)" above. If plutonium materials are dissolved in H-Canyon/HB-Line, existing process lines could be used with few modifications. The number of onsite shipments of waste from these modification activities would be expected to fall within the number of onsite shipments from H-Canyon/HB-Line that currently occur. Similarly, the number of onsite shipments from MFFF due to the addition of oxidation furnaces would not measurably increase above what would currently be expected from construction of MFFF.

Operations—Under this option, plutonium metals would be transported to H-Canyon/HB-Line for processing and oxidation. Pits would be disassembled and converted at LANL PF-4 and at the K-Area Complex. Under this option, it is possible to produce highly enriched uranium oxides as the final products in the H-Canyon/HB-Line. If the plutonium products from LANL are in metal forms, then they would be sent to SRS for oxidation; otherwise, they would be directly sent to the K-Area storage facility prior to being transported to MFFF. Oxidation could occur at H-Canyon/HB-Line or in furnaces at MFFF.

No intrasite transport of plutonium materials would occur at LANL. At SRS, about 410 shipments of plutonium materials (including certain feedstock materials) would occur from K-Area storage to MFFF. About 60 shipments of plutonium material could be transported from K-Area storage to H-Canyon/HB-Line for processing.

For onsite waste shipments, the total number of annual shipments can be obtained from Table E–16, including the shipments related to metal oxidation at MFFF, H-Canyon/HB-Line, and PF-4.

E.11.2 Onsite Shipments Related to Disposition Options

The number of onsite shipments of solid waste related to construction and operation impacts are presented for all applicable facilities in **Tables E–17** and **E–18**, while the number of shipments associated with transporting plutonium materials are presented in Section E.11.1.

Table E–17 Average Annual Number of Onsite Waste Shipments Due to Construction and Modifications for Disposition Options [a]

Facility	*TRU Waste to E-Area*	*LLW to E-Area*	*MLLW to E-Area*	*Hazardous Waste to E-Area*	*Solid Nonhazardous Waste to Three Rivers Landfill*
Immobilization Capability to E-Area	0	33	5	5	28
DWPF to E-Area	0	0	0	0	0
MFFF to E-Area	0	0	0	0	0
H-Canyon/HB-Line to E-Area	0	0	0	0	0
H-Canyon/HB-Line to E-Area (WIPP)	1	0	0	0	0

DWPF = Defense Waste Processing Facility; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fuel Fabrication Facility; MLLW = mixed low-level radioactive waste; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

[a] TRU waste, MLLW, and hazardous waste are assumed to be transported in 55-gallon drums, with 20 drums per shipment. LLW is assumed to be transported in B-25 boxes, with 5 boxes per shipment. Solid nonhazardous waste is assumed to be transported in a roll-off container, with 1 container per shipment.

Table E–18 Average Annual Number of Onsite Waste Shipments Due to Operations for Disposition Options [a]

Facility	*TRU Waste to E-Area*	*LLW to E-Area*	*MLLW to E-Area*	*Hazardous Waste to E-Area*	*Solid Nonhazardous Waste to Three Rivers Landfill*
Immobilization Capability to E-Area	120	20	20	20	3
DWPF to E-Area	0	1	0	0	0
MFFF to E-Area	66	35	0	1	66
H-Canyon/HB-Line to E-Area	13	11	0	0	0
H-Canyon/HB-Line to E-Area (WIPP)	190	6	0	0	0

DWPF = Defense Waste Processing Facility; LLW = low-level radioactive waste; MFFF = Mixed Oxide Fuel Fabrication Facility; MLLW = mixed low-level radioactive waste; TRU = transuranic; WIPP = Waste Isolation Pilot Plant.

[a] TRU waste, MLLW, and hazardous waste are assumed to be transported in 55-gallon drums, with 20 drums per shipment. LLW is assumed to be transported in B-25 boxes, with 5 boxes per shipment. Solid nonhazardous waste is assumed to be transported in a roll-off container, with 1 container per shipment.

Immobilization and DWPF

Construction—Low-level and mixed low-level radioactive waste and hazardous waste shipments would be required from K-Area to E-Area. In addition, there would be shipments of nonhazardous waste to the Three Rivers Landfill. Facility modifications at DWPF would be expected to be minimal to process can-in-canisters; therefore, no transport of waste materials would be expected.

Operation—If 13.1 metric tons (14.4 tons) of surplus plutonium is immobilized, then a total of about 95 can-in-canisters would be generated, requiring an equal number of shipments from K-Area to DWPF.

For immobilization capability operations, TRU waste, low-level and mixed low-level radioactive waste, and hazardous waste would require transport from K-Area to E-Area, as shown in Table E–18, while nonhazardous waste would require shipments from K-Area to the Three Rivers Landfill. There would be an annual shipment of low-level radioactive waste from DWPF to E-Area.

MOX Fuel Fabrication with Use in Commercial Nuclear Power Reactors

Construction—Construction of MFFF is not considered in this *SPD Supplemental EIS*. Modifications in H-Canyon/HB-Line to process plutonium material for conversion to MOX fuel at MFFF would not be extensive and would not be expected to generate enough wastes to increase the overall number of waste shipments from H-Canyon/HB-Line.

Operation—Annual transports of TRU and low-level radioactive waste would be required from MFFF in F-Area to E-Area. Nonhazardous waste also would be annually transported from F-Area to the Three Rivers Landfill.

H-Canyon/HB-Line and DWPF

Construction—There would be no construction or facility modification activities required at H-Canyon/HB-Line and DWPF that would generate any waste types above what is currently generated.

Operation—In performing these operations under the H-Canyon/HB-Line to DWPF Alternative, additional waste generation would be minimal and can be assumed to fall within the quantities normally generated by operations at DWPF. From H-Canyon/HB-Line, several shipments of TRU waste and low-level radioactive waste would occur annually to E-Area.

WIPP Disposal

Construction—A TRU waste shipment would be required annually from H-Area to E-Area due to modifications made in H-Canyon/HB-Line to prepare plutonium material for transport to WIPP.

Operation—Use of H-Canyon/HB-Line for preparing plutonium material would generate TRU and low-level radioactive waste.

E.11.3 Onsite Shipments Related to Support Activities

Support facilities include K-Area storage, K-Area Interim Surveillance, WSB, and E-Area. Transport of plutonium materials from K-Area storage is described in Section E.11.1. No construction or modification activities are considered in this *SPD Supplemental EIS* for the support facilities. Radioactive waste would be generated by K-Area Interim Surveillance and WSB operations, as shown in **Table E–19**. There would be no waste shipments associated with K-Area storage or E-Area.

Table E–19 Average Annual Number of Onsite Waste Shipments Due to Operations of Support Facilities [a]

Facility	*TRU Waste to E-Area*	*LLW to E-Area*	*MLLW to E-Area*	*Hazardous Waste to E-Area*	*Solid Nonhazardous Waste to Three Rivers Landfill*
KIS to E-Area	0	2	0	0	1
WSB to E-Area	50	25	0	0	18

KIS = K-Area Interim Surveillance; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; TRU = transuranic; WSB = Waste Solidification Building.

[a] TRU waste, MLLW, and hazardous waste are assumed to be transported in 55-gallon drums, 20 drums per shipment. LLW is assumed to be transported in B-25 boxes, 5 boxes per shipment. Solid nonhazardous waste is assumed to be transported in a roll-off container, 1 container per shipment.

E.12 Conclusions

Based on the results presented in the previous sections, the following conclusions have been reached (see Tables E–6 to E–10):

- For all alternatives, it is unlikely that the transportation of radioactive material and 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 due to incident-free transportation would be under the WIPP Alternative, where up to 10,300 truck shipments of radioactive materials, wastes, and unirradiated MOX fuel would be transported (see Table E–10).
- Transporting unirradiated FFTF fuel in HUFPs and using criticality control containers or direct disposition to transport pit and other non-pit plutonium as TRU waste to WIPP would not significantly change transportation risks for an alternative.
- The nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present greater risks than the radiological accident risks. Implementation of any of the alternatives could result in a traffic fatality, if shipment of unirradiated MOX fuel is included.
- Up to one traffic fatality would be expected over the duration of the activities (which exceeds 20 years for all the alternatives) evaluated in this *SPD Supplemental EIS*. For comparison, in the United States in 2010 there were over 3,900 fatalities due to crashes involving large trucks (DOT 2012b) and over 32,000 traffic fatalities due to all vehicular crashes (DOT 2012c). The incremental increase in risk to the general population from shipments associated with the surplus plutonium disposition program would therefore be very small and would not substantially contribute to cumulative impacts.

E.13 Long-term Impacts of Transportation

The *Yucca Mountain EIS* (DOE 2002a, 2008b) analyzed the cumulative impacts of the transportation of radioactive material, consisting of impacts of historical shipments of radioactive waste and used 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 the LCFs, using a cancer risk coefficient. **Table E–20** 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 small compared with the overall transportation impacts. The total collective worker dose from all types of shipments (the alternatives in this *SPD Supplemental EIS*; historical, reasonably foreseeable actions; and general transportation) was estimated to be about 421,000 person-rem (253 LCFs) for the period from 1943 through 2073 (131 years). The total general population collective dose was estimated to be about 436,000 person-rem (262 LCFs). The majority of the collective dose for workers and the general population is 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 radioactive 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 515, or an average of about 4 LCFs per year. Over this same period (131 years), approximately 73 million people would die from cancer, based on National Center for Health Statistics data. The average annual number of cancer deaths in the United States from 2004 through 2008 is about 560,000, with less than 1 percent fluctuation in the number of cancer fatalities from one year to the next (CDC 2007, 2008a, 2008b, 2011a, 2011b). The transportation-related LCFs would be 0.0009 percent of the total annual number of LCFs; therefore, this number is indistinguishable from the natural fluctuation in the total annual death rate from cancer.

Table E–20 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 *SPD Supplemental EIS* [a]	230 – 650	150 – 580
Other Nuclear Material Shipments [b]		
Site-Specific Historical	49	25
Past, Present, and Reasonably Foreseeable DOE Actions	31,400	36,900
Past, Present, and Reasonably Foreseeable non-DOE Actions [c]	5,380	61,300
General Radioactive Material Transport (1943 to 2073)	384,000	338,000
Total Collective Dose (through 2073)	421,000	436,000
Total Latent Cancer Fatalities [d]	252	262

[a] Range of values from Tables E–6 to E–10.

[b] The values are rounded. See Chapter 4, Section 4.5.3.7, for more detail regarding how these impacts were derived.

[c] Non-DOE activities include operation of four new nuclear fuel manufacturing facilities and operations at two new nuclear power reactors at the Vogtle Electric Generating Plant.

[d] Total LCFs are calculated assuming 0.0006 LCFs per rem of exposure (DOE 2003b).

E.14 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 (e.g., approximate algorithms used within the computer codes).

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 significantly affect the risk assessment results are identified.

E.14.1 Uncertainties in Material Inventory and Characterization

The inventories and the 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, and assumptions concerning shipment capacities. The physical and radiological characteristics are important in determining the material released during accidents and the subsequent doses to exposed individuals through multiple environmental exposure pathways.

Uncertainties in the inventory and characterization are reflected in the transportation risk results. If the inventory is overestimated (or underestimated), the resulting transportation risk estimates 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 Tables E–6 through E–10, are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

E.14.2 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.

One factor that can influence shipment capacities for TRU waste using TRUPACT II packages, and therefore the number of shipments, is the use of dunnage. Dunnage is secured space not occupied by waste or waste containers. Dunnage may be used to keep the entire payload from shifting position during transit or when the payload has reached one or more shipping limits for parameters such as weight, gas generation, radioactivity, or fissile mass (Casey 2007). Use of dunnage was factored into determining the number of shipments of surplus plutonium and TRU waste to WIPP. The impact of dunnage on the determination of number of shipments is highly variable among DOE sites and even among individual waste streams; however, to give an idea as to its impact, historically dunnage has comprised less than 10 percent of the TRU waste volume transported from DOE sites to WIPP. If the number of shipments of incidental TRU waste associated with this *SPD Supplemental EIS* was increased by this amount, it would have a negligible impact on the results for each alternative. As in the case of variations in shipment capacities addressed in the previous paragraph, incorporation of factors related to dunnage into shipment calculations would not change the relative differences in risks among alternatives.

E.14.3 Uncertainties in Route Determination

Analyzed routes have been determined between all origin and destination sites considered in this *SPD Supplemental EIS*. 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 ones that are analyzed 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 significantly affect relative comparisons of risk among the alternatives considered in this *SPD Supplemental EIS*.

E.14.4 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 (i.e., urban, suburban, or 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 intended to produce conservative results (i.e., overestimate 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.

E.14.5 Uncertainties in Traffic Fatality Rates

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). Truck and rail accident rates were computed for each state based on statistics compiled by the Federal Highway Administration, Office of Motor Carriers and Federal Railroad Administration, from 1994 to 1996. The rates are provided per unit car-kilometers for each state, as well as national average and mean values. In this analysis, route-specific (origin-destination) rates were used.

Finally, it should be emphasized that the analysis was based on accident data for the years 1994 through 1996. While this data may be the best available data, future accident and fatality rates may change as a result of vehicle and highway improvements. The recent U.S. DOT national accident and fatality statistics for large trucks and buses indicates lower accident and fatality rates for recent years compared to those of 1994 through 1996 and earlier statistical data (DOT 2009).

E.15 References

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