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 *Versatile Test Reactor Environmental Impact Statement* (VTR EIS) alternatives and options, this appendix assesses the human health risks associated with the transportation of radioactive materials and wastes, as well as nonradioactive construction materials and hazardous waste, on public highways.

This appendix provides an overview of the approach used to assess the human health risks that could result from transportation of VTR-related materials. 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 EIS 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 on transportation infrastructure are addressed in Chapter 4, Section 4.13, of this VTR 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 transportation accident conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of 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, 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 (see Title 10 of the *Code of Federal Regulations* [CFR], Part 20 [10 CFR Part 20]). 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. (That is to say, nonradiological causes would be related to the transport vehicles, not to 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 and a Motor Carrier Evaluation Program approved commercial carrier. In addition to the use of commercial carriers 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 (NNSA) Secure Transportation Asset (STA), which consists of truck transport only. (No rail transport is analyzed because rail is not part of the 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 STA. Transport of unirradiated VTR fuel is also assumed to occur using the STA.

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 elements 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

[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."

- Established operational and emergency plans and procedures governing the shipment of nuclear materials
- Federal agents who are armed officers and have received vigorous specialized training
- An armored tractor component that provides Federal agents 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 0.5 miles of each side of the highway. 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 50 miles of the accident, and the MEI would be an individual located 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 general 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. Instead DOE uses 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 placing 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 detailed CFR regulations pertaining to the transportation of radioactive materials are published by DOT at 49 CFR Parts 106, 107, and 171 to 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* for a comprehensive discussion on radioactive material regulations (DOT 2008).

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 materials being transported and radiation exposure to the public, workers, and the environment. Transportation packaging for radioactive materials must be designed, constructed, and maintained to contain and shield its contents during normal transport conditions. For highly radioactive material, such as high-level radioactive waste or spent nuclear fuel, packaging must contain and shield the contents in the event of a severe accident. 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 low levels of radioactivity, 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 Type A packages are used to transport materials with higher radioactive content, they must maintain sufficient shielding to limit radiation exposure to handling personnel. Type A packaging, typically a 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 materials with the highest radioactivity levels and is designed to protect and retain its contents under transportation accident conditions. (These conditions are described in more detail in later 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 Fahrenheit (°F) to 158 °F
- External pressures ranging from 3.5 to 20 pounds per square inch
- Normal vibration experienced during transportation
- Simulated rainfall of 2 inches per hour for 1 hour
- Free fall from 1 to 4 feet, depending on the package weight
- Water immersion tests
- Impact of a 13-pound steel cylinder with rounded ends dropped from 3.3 feet onto the most vulnerable surface
- A compressive load of 5 times the mass of the gross weight of the package for 24 hours, or the equivalent of 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 30 feet onto an unyielding surface in a position most likely to cause damage
- Free drop from 3.3 feet onto the end of a 6-inch-diameter vertical steel bar
- Exposure to temperatures of 1,475 °F for at least 30 minutes
- For all packages, immersion in at least 50 feet of water
- For some packages, immersion in at least 3 feet of water in an orientation most likely to result in leakage
- For some packages, immersion in at least 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 specify the maximum dose rate from radioactive material shipments to help reduce incident-free transportation doses.

E.4 Emergency Response

The U.S. Department of Homeland Security (DHS) is responsible for establishing and coordinating policies for 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 that a transportation incident involving nuclear material occurs, guidelines for response actions have been outlined in the *National Response Framework* (DHS 2019).

The Federal Emergency Management Agency, an organization within DHS, coordinates Federal and State participation in developing emergency response plans and is responsible for the development and maintenance of the *Nuclear/Radiological Incident Annex* (DHS 2016) to the *National Response Framework* (DHS 2019). The *Nuclear/Radiological Incident Annex* to the *National Response Framework* 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.

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. They 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 151.1D *Comprehensive Emergency Management System* (DOE 2016b) as a basis for establishing a comprehensive emergency management program. The program's order 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 that 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 151.1D.

In the event of a release of radiological cargo from a shipment along a route, local emergency response personnel would be first to arrive at the accident scene. It is expected that response actions would be taken in the context of the *Nuclear/Radiological Incident Annex* protocols. Based on their initial assessment at the scene, trained and fully equipped first responders would involve State and Federal resources as necessary. First responders or State and Federal responders would initiate actions in accordance with the DOT *2016 Emergency Response Guidebook* (DOT 2016) to isolate the incident and perform any actions necessary to protect human health and the environment. (Responses could include evacuations or other steps to reduce or prevent impacts on 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 that 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 VTR 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.

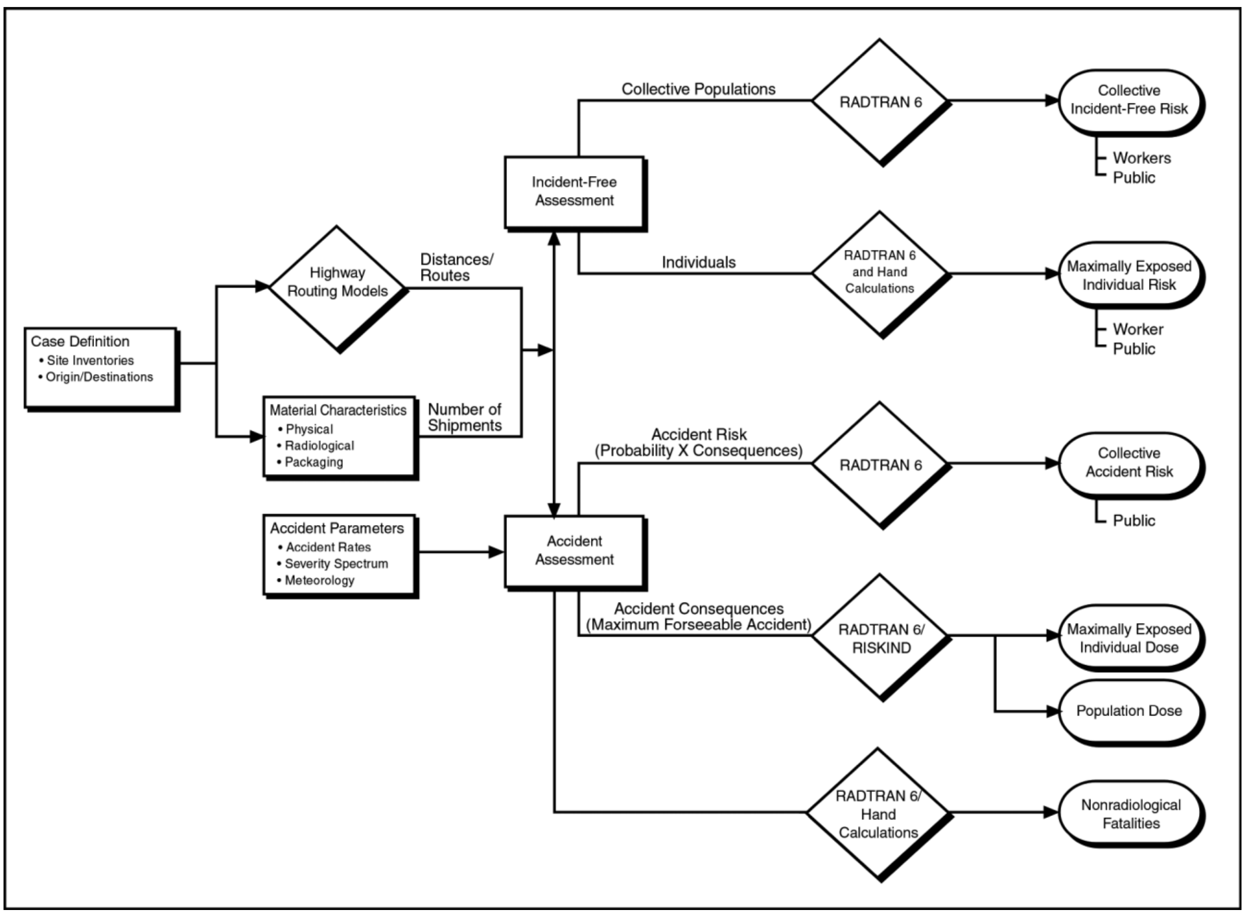

Figure E–1. Transportation Risk Assessment

Transportation impacts calculated for the VTR 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 and lead to releases of radioactive materials to the environment.

The impact of transportation accidents is expressed in terms of probabilistic risk. Probabilistic risk 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) and subsequently in *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.

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 Web Transportation Routing Analysis Geographic Information System (WebTRAGIS) computer program (Peterson 2018) 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 (Weiner et al. 2013, 2014), 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) (Weiner et al. 2013, 2014). 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 was used to estimate the doses to MEIs and populations for the worst-case maximum reasonably foreseeable transportation accident (Yuan et al. 1995). The RISKIND computer code was developed for the DOE 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. This code is also applicable to the 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 VTR EIS is consistent with direction provided in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002b).

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 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 could occur as part of routine operations:

- Plutonium materials (weapons-grade in metal or oxide form) from either Los Alamos National Laboratory (LANL) to the Savannah River Site (SRS) or the Idaho National Laboratory (INL) or from SRS to INL;[2]
- Plutonium materials (reactor-grade in oxide form) from Europe (France, United Kingdom, or both) through Joint Base Charleston-Weapons Station in South Carolina to SRS or INL;
- Transuranic (TRU) waste (both contact-handled [CH] and remote-handled [RH]) from SRS, INL, and Oak Ridge National Laboratory (ORNL), as applicable, to the Waste Isolation Pilot Plant (WIPP) in New Mexico;
- Unirradiated VTR fuel assemblies from SRS to INL or ORNL, or from INL to ORNL;
- Low-level and mixed low-level radioactive wastes from SRS, INL, and ORNL to offsite Federal or commercial disposal facilities. For purposes of analysis in this EIS, the disposal site was assumed to be the Nevada National Security Site (NNSS) near Las Vegas, Nevada; Energy*Solutions* near Clive, Utah; or Waste Control Specialists, near Andrews, Texas;
- Low-enriched uranium (LEU) (5-percent) from a commercial fuel fabrication facility (e.g., Nuclear Fuel Services, Inc. (NFS), in Erwin, Tennessee) to SRS or INL;
- Adulterant from a commercial vendor from an assumed distance of 3,000 miles or from diluent from a DOE site to INL or SRS, for dilution of plutonium wastes in critically controlled overpacks for transport to the WIPP facility;
- Construction materials shipped to SRS, INL, or ORNL (nonradiological impacts only);
- Hazardous waste from SRS, INL, and ORNL to an offsite treatment, storage, and disposal facility (nonradiological impacts only).

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

For offsite transport, highway routes were determined using the routing program WebTRAGIS (Peterson 2018). WebTRAGIS 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

[2] The weapons-grade plutonium would be available from LANL or SRS after pit disassembly at either site. The impacts of transporting surplus pit to either site were evaluated in the SPD SEIS (DOE 2015a).

of the Census Topological Integrated Geographic Encoding and Referencing System. The features in WebTRAGIS 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 2010 Census Bureau data (Peterson 2018). 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 2050 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 VTR *EIS* are summarized in **Table E–1**. Rural, suburban, and urban areas are characterized according to the following breakdown (Peterson 2018):

- 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 0.5 miles of each side of the transportation route.

Analyzed truck routes for offsite shipments of radioactive materials and wastes for the INL VTR Alternative and ORNL VTR Alternative are shown in **Figure E–2** and **Figure E–3**, respectively. **Figure E–4** shows additional routes that are common to both alternatives.

Table E–1. Offsite Transport Truck Route Characteristics

Origin	*Destination*	*Nominal Distance (kilometers)*	*Distance Traveled in Zones (kilometers)*			*Population Density in Zone* [a] *(number per square kilometer)*			*Number of Affected Persons* [b]
			Rural	*Suburban*	*Urban*	*Rural*	*Suburban*	*Urban*	
INL	NNSS	1,330	1,178	129	22	15	951	3,608	**354,070**
INL	ORNL [c]	3,320	2,624	639	57	21	626	2,342	**944,151**
SRS	INL [d]	3,753	2,809	838	107	23	712	2,806	**1,534,658**
INL	WIPP	2,285	1,935	297	54	21	769	3,551	**733,501**
NFS [e]	INL	3,545	2,747	726	71	23	633	2,344	**1,101,435**
ORNL	NNSS	3,466	2,837	564	66	18	593	2,951	**929,802**
SRS	ORNL [c]	621	327	250	45	36	858	3,454	**609,287**
SRS	NNSS	3,890	3,105	760	115	20	682	3,161	**1,502,998**
ORNL	WIPP	2,082	1,527	502	54	25	722	2,888	**887,811**
NFS [e]	SRS	488	287	192	9	35	549	2,525	**220,027**
LANL	SRS	2,722	1,980	652	90	25	655	3,119	**1,211,384**
LANL	INL	1,895	1,519	322	54	26	743	3,551	**751,812**
SRS	WIPP	2,307	1,596	681	30	25	587	2,745	**836,719**
JWS	SRS	222	145	67	10	17	948	3,034	**154,511**
INL	Energy*Solutions*	511	381	108	22	27	992	3,608	**317,354**
INL	WCS	2,365	2,007	303	55	20	772	3,521	**748,407**

Origin	Destination	Nominal Distance (kilometers)	Distance Traveled in Zones (kilometers)			Population Density in Zone [a] (number per square kilometer)			Number of Affected Persons [b]
			Rural	Suburban	Urban	Rural	Suburban	Urban	
ORNL	Energy*Solutions*	3,145	2,458	615	73	21	668	2,704	**1,054,278**
ORNL	WCS	1,963	1,415	496	52	26	719	2,903	**872,653**
SRS	Energy*Solutions*	3,572	2,636	814	122	22	747	2,962	**1,644,834**
SRS	WCS	2,182	1,478	675	29	27	584	2,764	**821,614**
DOE site 1	INL	3,387	2,674	647	66	21	594	2,483	**966,123**
DOE site 1	SRS	947	489	435	24	31	637	2,682	**568,421**
DOE site 2	INL	2,864	2,303	511	51	20	611	2,351	**767,812**
DOE site 2	SRS	930	528	347	55	32	838	3,226	**777,857**

INL = Idaho National Laboratory, JWS = Joint Base Charleston-Weapon Station; LANL = Los Alamos National Laboratory; NFS = Nuclear Fuel Services, Inc.; NNSS = Nevada National Security Site; OH = Ohio; SRS = Savannah River Site; WCS = Waste Control Specialists; WIPP = Waste Isolation Pilot Plant.

[a] Population densities have been projected to 2050 using State-level data from the 2010 census (Census 2010) and assuming State population growth rates from 2000 to 2010 continue to 2050.

[b] For offsite shipments, the estimated number of persons residing within 800 meters (0.5 miles) along the transportation route, projected to 2050.

[c] Shipments of VTR fuel assemblies would be from SRS or INL to ORNL, if VTR is at ORNL

[d] Shipments of plutonium materials would be made from SRS or LANL to INL, or from LANL to SRS, depending on the options for feedstock preparation and fuel production facilities (e.g., at INL or at SRS).

[e] Shipment of 5-percent enriched uranium metal is assumed to be from Nuclear Fuel Services, Inc., in Erwin, Tennessee.

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.

Figure E–2. Analyzed National and Regional Truck Routes for the INL VTR Alternative

Figure E–3. Analyzed National and Regional Truck Routes for the ORNL VTR Alternative

Figure E–4. Additional Routes that are Common to Both Alternatives

E.5.2 Radioactive Material Shipments

Transportation of all material and waste types is assumed to occur in certified or certified-equivalent packaging on dedicated-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 48,000 pounds, based on the Federal gross vehicle weight limit of 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 8.5 feet (23 CFR 658.15). Length restrictions vary by State, but are assumed for purposes of analysis to be no more than 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 VTR 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.

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 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 in the form of metal or oxides, enriched uranium, and VTR fuel. These shipments would occur to support production of VTR fuel fabrication and its transport to the VTR site. The numbers of shipments associated with the transport of plutonium, and uranium (low- or high-enriched) were determined using up-to-date information regarding the types of transport packages to be used and forecasted VTR assembly needs. 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, 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 VTR fuel, the number of shipments is based on three assemblies per transport package, one transport package per shipment (INL 2020c).

For the LEU (5-percent enriched), the quantities required for the VTR are assumed to be transported in ES 3100 packages using STAs. If LEU metal is used, then, the required materials are assumed to be shipped from a fabrication facility in Erwin, Tennessee (NFS) to SRS or INL.

[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 3.3 feet from the package (10 CFR 71.4 and 49 CFR 173.403).

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
MLLW	55-gallon drum	0.2	399	80 drums per truck
LLW	B-25 box	2.55	4,536	5 boxes per truck
CH-TRU waste	55-gallon drum	0.2	142 [d]	14 drums per TRUPACT-II; 3 TRUPACT-IIs per truck
CH-TRU waste	Pipe overpack container [e]	0.2	142 [d]	14 containers per TRUPACT-II; 3 TRUPACT-IIs per truck
Special nuclear material	Type B package	0.13 to 0.30	183-318	1 to 30 packages per STA
Unirradiated VTR fuel	Type B package [f]	9.3	6,350	1 transport cask per STA
TRU waste associated with the diluted processed plutonium	Criticality control container [g]	0.2	142	14 containers per TRUPACT-II
RH-TRU wastes	55-gallon drum	0.2	399	3 drums per RH-72B cask, 1 cask per truck
RH-LLW/MLLW	55-gallon drum	0.2	399	10 drums per CNS 10-160B cask, 1 cask per truck
LLW/MLLW	B-25 box	2.92	3,630	5 boxes per truck
LLW/MLLW	B-12 box	1.46	3,630	5 boxes per truck
LLW/MLLW	16-foot container	29	Not applicable	1 container per truck
Diluent	Type A package	4.04	13,800	1 cylinder per truck
Construction/demolition debris	Roll-on/Roll-off dumpster	15.30	Not applicable	1 load per truck
Hazardous waste	55-gallon drum	0.2	399	40 drums per truck

CH-TRU = contact-handled transuranic; CNS = Chem-Nuclear Systems, Inc.; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; RH = Remote-handled; 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] For the 14 drums per TRUPACT-II and three TRUPACT-II per shipment, the average weight of the drum is limited to 142 kilograms.

[e] TRU waste consisting of plutonium would be packaged in pipe overpack containers (POCs), which would be the same size as a 55-gallon drum.

[f] Packages for transporting VTR fuel assemblies are assumed to be the Hanford Unirradiated Fuel Package.

[g] Diluted processed plutonium oxide would be packaged in the criticality control containers, which would be the same size as a 55-gallon drum.

The quantities of the uranium and plutonium source material (e.g., feedstock) needs are based on the VTR fuel design specifications as discussed in the *VTR Fuel Facility Plan* (INL 2019a), the *Conceptual Design Report for the Versatile Test Reactor* (INL 2019b), and the SRS Data Call Response (SRNS 2020). Essentially, the VTR operation requires 45 fresh fuel assemblies per year. Depending on the type of fuel (e.g., a clean weapons-grade fuel with low impurities or the more common plutonium materials with impurities, (especially the in-growth americium-241), different fabrication or pre-fabrication processing would be needed to produce plutonium feed materials that meet the VTR fuel specification needs (e.g., americium-241 content of less than 1 percent). Given the processing efficiency (SRNL 2020), between 460 to 550 kilograms of plutonium and 1,610 to 1,920 kilograms LEU per year would be needed for feedstock.

For radioactive waste to be transported to a radioactive waste disposal site, it is assumed that the wastes would meet the disposal facility's waste acceptance criteria. For purposes of analysis, it is assumed that all of the low-level radioactive waste generated at INL, ORNL, or SRS would be transported to NNSS, Energy*Solutions*, or WCS for disposal.

TRU waste would be transported to WIPP for disposal. TRU waste would consist of secondary waste resulting from VTR fuel production (plutonium preparation and fuel fabrication) activities and treatment of spent nuclear fuel. These materials could be packaged in drums, pipe overpack containers (POCs), or criticality control overpacks (CCOs). Use of CCOs for disposal of plutonium materials allows a higher concentration, thereby reducing the number of shipments and disposal volume.

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 the table is limited to those that would be expected from the plutonium wastes during the fuel fabrication and spent fuel treatment activities. The composition of the waste is the average curie concentration per radioisotope as measured in the year 2010. This composition is assumed to be representative of the low-level and mixed low-level radioactive waste streams generated by plutonium processing and disposition activities (DOE 2015a).

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

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: DOE 2015a; SRNS 2012.

The various wastes that would be generated from the VTR operation, and its support facilities, including the post-irradiation examination operations, are estimated in *Versatile Test Reactor Wastes and Material Data for Environmental Impact Statement* (INL 2020b). This INL report provides the estimated volumes of different wastes from each facility operation, along with the expected radionuclide inventories for each type of waste from each facility. This compilation of waste data would lead to about 20 different waste-radionuclide combinations. For the purposes of this VTR EIS, the analysis in this appendix assigns a set of radionuclides to each waste type, regardless of its origin. This action reduces the waste-radionuclide combinations to four categories: CH- and RH-low-level; mixed low-level wastes; CH- and RH-TRU; and mixed TRU wastes. The selected lists of radionuclides are based on information in the INL report, in which the transportation accident would lead to a maximum population dose for each selected waste type.

The various wastes from the VTR and its support facility operations are assumed to be packaged for transportation to an offsite disposal facility by considering these four factors:

1. CH-low-level and mixed low-level wastes are packaged in B-12 boxes (20 percent), B-25 boxes (20 percent), and 16-foot ISO containers (60 percent), for transport to a disposal facility.

2. RH-low-level and mixed low-level wastes are packaged in 55–gallon drums and placed in a Type B shielded casks for transport to a disposal facility; CNS 10-160B (COC-71-9204 2020) was used a representative transport package.
3. RH-TRU and mixed TRU wastes are packaged in 55-gallon drums and placed in Type B shielded casks for transport to WIPP; RH-72B (COC-71-9212 2019) was used as a representative transport package.
4. CH-TRU and mixed TRU wastes are packaged in 55-gallon drums and placed in TRUPACT-II for transport to WIPP.

Given the feedstock preparation and VTR fuel production efficiency (SRNL 2020), the VTR operation would require up to 34 metric tons of plutonium feedstock materials.[4] The U.S. excess plutonium inventory of more than 50 metric tons would be sufficient to meet fueling needs for the VTR lifetime operation of 60 years. This inventory includes metallic, weapons-grade plutonium managed by the National Nuclear Security Administration, as well as non-weapons-grade material and material in different physical forms. Therefore, the sources for needed plutonium could range from domestic surplus U.S. weapons-grade and non-weapons-grade forms to optional reactor-grade material procured from Europe (France, United Kingdom, or both).

For transport of the weapons-grade plutonium from LANL, the reactor-grade plutonium from Europe, and the LEU from NFS to the VTR fuel production facilities, 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 the new (unirradiated) VTR fuel assembly. For transport of the new fuel assemblies, it was assumed that the Hanford Unirradiated Fuel Package would be used (INL 2020c). This package was constructed for transporting Fast Flux Test Facility (FFTF) and Experimental Breeder fuel with an assembly length up to 12 feet (CH2MHILL 2009). The use of this package would require some reassembly of non-fuel part of the VTR fuel, because of the overall assembly length differences between the VTR and FFTF fuel.

Table E–4. Radioisotopic Content of Transport Packages Containing New VTR Fuel Assemblies

	VTR Fuel Assemblies Curies per Package [a]			
Radioisotope	***Weapons-Grade Plutonium***	***Reactor-Grade Plutonium***	***Radioisotope***	***VTR Fuel Assemblies Curies per Package*** [a]
Americium-241	3.20	36.9	Uranium-232	0.00391
Plutonium-238	227	9,540	Uranium-234	1.61
Plutonium-239	1,530	1,030	Uranium-235	0.010
Plutonium-240	362	1,510	Uranium-236	0.150
Plutonium-241	27,400	110,000	Uranium-238	0.0289
Plutonium-242	0.104	6.89		

[a] Each package is assumed to contain three VTR fuel assemblies.

For the disposition of the plutonium wastes from fabrication without the need for feedstock preparation (e.g., use of cleaner weapons-grade plutonium feed), the waste would be oxidized and repackaged and sent to WIPP for disposal. For purposes of analysis, it was assumed there would be 150 grams of plutonium per POC and 300 grams of plutonium per CCO. A shipment would consist of three TRUPACT-II [Transuranic Package Transporter Model 2] packages, each containing 13 containers. [The selection of 13 containers per TRUPACT-II is based on the uncertainty of the total mass limit of the drums within the package. This will lead to a slightly larger number of shipments.]

[4] This is an upper estimate based on the fuel production efficiency of about 73 percent for fabrication without feedstock preparation. As the production efficiency improves, the need for the feedstock plutonium could be reduced.

If the plutonium feed requires pre-processing for the removal of impurities prior to fuel fabrication, three potential cases are considered (SRNL 2020):

1. Case 1 Aqueous processing
2. Case 2 Pyro-chemical processing with aqueous processing
3. Case 3 Pyro-chemical processing

The generated wastes in Cases 1 and 3 envelope the range of potential waste values for disposition. It was considered that Case 1 would generate cemented drums of americium-plutonium content limited to a total of 80 curies (minus the uncertainty, which was assumed to be 13 percent) per drum, whereas Case 3 would generate metal drums of americium-plutonium content limited to 80 curies (minus the uncertainty, which was assumed to be 22 percent) per drum (SRNL-2020). For the transport to WIPP, because of the limitations on container loads, it was considered that there would be 12 cemented americium-plutonium waste containers per shipment, and 28 metal americium-plutonium waste containers per shipment.

For the secondary TRU waste generated from processing of weapons-grade plutonium, it was assumed there would be 20 grams of plutonium per drum. For TRU waste generated from processing non-weapons-grade plutonium, it was assumed there would be 10 grams of plutonium per drum. A shipment of TRU waste would consist of three TRUPACT-II packages.

The feedstock (plutonium and uranium) could be in the form of metal, powder, or both. The European plutonium is in oxide powder form. There is also a domestic weapons-grade plutonium that is in oxide form. Therefore, for analysis purposes and to conservatively envelop the risk of transporting plutonium and uranium source materials to the VTR fuel production facility option locations, it was assumed that these source materials (e.g., feedstock) would be in oxide form (e.g., powder) to maximize the accident risks. In addition, the impact analysis is based on the weapons-grade (lowest risk) and European (highest risk) plutonium materials, as these provide an enveloping risk for all other potential domestic plutonium that could be transported between the affected sites.

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.

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 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 4.10 of the VTR 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 (Weiner et al. 2013, 2014). 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 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 shows 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 shielded Type A or Type B shipping container. The waste container dose rate at 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 CH- and RH-low-level and mixed low-level radioactive waste were assigned a dose rate of 2 and 10 millirem per hour at 3.3 feet, and the LEU was assigned a dose rate of 2 millirem per hour at 3.3 feet. The dose rate for packages containing unirradiated VTR fuel is assumed to be 1 millirem per hour at 3.3 feet from the transport vehicle. For the plutonium oxide, the dose rate is assumed to be 5 millirem per hour at 3.3 feet from the transport vehicle. A dose rate of 1 millirem per hour at 3.3 feet was assigned to packages containing diluent. The dose rates for CH-TRU and RH-TRU waste were assumed to be 4 and 7 millirem per hour at 3.3 feet, respectively (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 6.6 feet 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 (49 CFR Parts 171 to 178 requires use of these roadways 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 *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 4.4.

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 4 feet from the surface of the shipping container for 30 minutes

- A resident living 98 feet from the highway used to transport the shipping container
- A service station worker at a distance of 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 in 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 exposures as low as reasonably achievable. DOE has, therefore, established the administrative control level of 2 rem per year per person (DOE 2017a). 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 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 50 miles were determined using the RADTRAN 6 computer program (Weiner et al. 2013, 2014). 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 on 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 0.5 miles from the accident location. This dose is an external dose, and is inversely proportional to the square of the distance of the affected population from an accident. Any additional dose to those residing beyond 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 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 techniques, there is a risk of traffic accidents. DOE and its predecessor agencies have a successful 50-year history of transporting radioactive materials.

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 than other truck drivers.

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 route-specific accident rates and accident fatality risks were used. The values selected were the total State-level accident and fatality rates provided in ANL/ESD/TM-150 (Saricks and Tompkins 1999). The State-level rates were adjusted based on the distance traveled 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 (Blower and Matteson 2003). 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, and 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) were 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 wind speeds, vertical mixing within the atmosphere, and good dispersion of atmospheric contaminants. Stable weather conditions are typified by low wind speeds, 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 3.3 feet per second) and neutral (Class D with a wind speed of 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 non-dispersible.

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 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., 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 RH-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 are undamaged and no radioactive material is released, it is 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 is assumed to stay 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 VTR 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 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 rem 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 VTR *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 VTR *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 2050. 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).

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

Material or Wastes	Origin	Transport Destination	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk (LCF)	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk (LCF)	Accident: Radiological Risk (LCF)	Accident: Non-radiological Risk (traffic fatalities)
Plutonium [a, b]	LANL	SRS	0.034	$2.0×10^{-5}$	0.12	$7.4×10^{-5}$	$1.0×10^{-7}$	0.000075
TRU waste (primary) in POCs containing WG plutonium material [c]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$1.3×10^{-8}$	0.00014
TRU waste (secondary) with 20 grams WG per drum [d]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$2.3×10^{-8}$	0.00014
TRU waste (primary) in CCOs containing WG plutonium material [e]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$2.4×10^{-8}$	0.00014
TRU (Am-241 in POCs) [c]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$1.1×10^{-7}$	0.00014
Plutonium [a, b]	LANL	INL	0.023	$1.4×10^{-5}$	0.083	$5.0×10^{-5}$	$7.2×10^{-8}$	0.000033
Plutonium [a, b]	SRS	INL	0.047	$2.8×10^{-6}$	0.17	$1.0×10^{-4}$	$1.4×10^{-7}$	0.000084
TRU waste (primary) in POCs containing WG plutonium material [c]	INL	WIPP	0.087	$5.2×10^{-5}$	0.072	$4.3×10^{-5}$	$1.2×10^{-8}$	0.000095
TRU waste (secondary) with 20 grams WG per drum [d]	INL	WIPP	0.087	$5.2×10^{-5}$	0.072	$4.3×10^{-5}$	$2.1×10^{-8}$	0.000095
TRU waste (primary) in CCOs containing WG plutonium material [e]	INL	WIPP	0.087	$5.2×10^{-5}$	0.072	$4.3×10^{-5}$	$2.1×10^{-8}$	0.000095
TRU (Am-241 in POCs) [c]	INL	WIPP	0.087	$5.2×10^{-5}$	0.072	$4.3×10^{-5}$	$1.1×10^{-7}$	0.000095
LLW/MLLW (B-25) [f]	SRS	NNSS	0.078	$4.7×10^{-5}$	0.052	$3.1×10^{-5}$	$4.0×10^{-10}$	0.00018
MLLW [f, g]	SRS	NNSS	0.094	$5.6×10^{-5}$	0.10	$6.2×10^{-5}$	$7.8×10^{-10}$	0.00018
MLLW [f, g]	INL	NNSS	0.032	$1.9×10^{-5}$	0.034	$2.0×10^{-5}$	$2.2×10^{-10}$	0.000055
LLW/MLLW (B-25) [f]	INL	NNSS	0.026	$1.6×10^{-5}$	0.017	$1.0×10^{-5}$	$1.1×10^{-10}$	0.000055
LLW/MLLW (B-25) [f]	INL	Energy*Solutions*	0.011	$6.2×10^{-6}$	0.011	$6.4×10^{-6}$	$1.2×10^{-10}$	0.000059
LLW/MLLW (B-25) [f]	INL	WCS	0.047	$2.8×10^{-5}$	0.043	$2.6×10^{-5}$	$2.7×10^{-10}$	0.00011
LLW/MLLW (B-25) [f]	SRS	Energy*Solutions*	0.072	$4.3×10^{-5}$	0.073	$4.4×10^{-5}$	$6.7×10^{-11}$	0.00019
LLW/MLLW (B-25) [f]	SRS	WCS	0.044	$2.6×10^{-5}$	0.044	$2.7×10^{-5}$	$4.0×10^{-11}$	0.00014
TRU waste	ORNL	WIPP	0.08	$4.8×10^{-5}$	0.069	$4.1×10^{-5}$	$8.9×10^{-10}$	0.00014
5%-Enriched Uranium [a, b]	NFS	SRS	0.0028	$1.7×10^{-6}$	0.0088	$5.3×10^{-6}$	$6.6×10^{-11}$	0.000013
5%-Enriched Uranium [a, b]	NFS	INL	0.02	$1.2×10^{-5}$	0.06	$3.6×10^{-5}$	$3.0×10^{-10}$	0.000073
VTR Fuel Assemblies	SRS	INL	0.0039	$2.4×10^{-6}$	0.014	$8.5×10^{-6}$	$4.1×10^{-9}$ ($8.6×10^{-10}$) [h]	0.000072
VTR Fuel Assemblies	SRS	ORNL	0.0007	$4.0×10^{-7}$	0.0027	$1.6×10^{-6}$	$1.3×10^{-9}$ ($2.7×10^{-10}$) [h]	0.000011
VTR Fuel Assemblies	INL	ORNL	0.0035	$2.1×10^{-6}$	0.012	$7.2×10^{-6}$	$3.0×10^{-9}$ ($6.3×10^{-10}$) [h]	0.000067
Plutonium From Europe [i]	JWS	SRS	0.0025	$1.5×10^{-6}$	0.0052	$3.1×10^{-6}$	$6.7×10^{-8}$ ($2.7×10^{-8}$) [j]	0.0000061
Plutonium (European) [k]	SRS	INL	0.047	$2.8×10^{-6}$	0.17	$1.0×10^{-4}$	$8.7×10^{-7}$ ($3.5×10^{-7}$) [j]	0.000084
TRU waste (primary) in POCs containing RG plutonium material [c]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$7.3×10^{-8}$	0.00014
TRU waste (secondary)with 10 grams RG per drum [d]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$3.5×10^{-8}$	0.00014
TRU waste (primary) in CCOs containing RG plutonium material [e]	SRS	WIPP	0.089	$5.3×10^{-5}$	0.075	$4.5×10^{-5}$	$1.4×10^{-7}$	0.00014

Material or Wastes	Origin	Transport Destination	Incident-Free				Accident	
			Crew Dose (person-rem)	Crew Risk (LCF)	Population Dose (person-rem)	Population Risk (LCF)	Radiological Risk (LCF)	Non-radiological Risk (traffic fatalities)
TRU waste (primary) in POCs containing RG plutonium material [c]	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	7.0×10^{-8}	0.000095
TRU waste (secondary)with 10 grams RG per drum [d]	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	3.3×10^{-8}	0.000095
TRU waste (primary) in CCOs containing RG plutonium material [e]	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	1.4×10^{-7}	0.000095
TRU: CASE-1 WG drummed waste [L]	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	2.2×10^{-8}	0.000095
TRU: CASE-1 WG drummed waste	SRS	WIPP	0.089	5.3×10^{-5}	0.075	4.5×10^{-5}	1.9×10^{-8}	0.00014
TRU: CASE-1 RG drummed waste	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	3.4×10^{-8}	0.000095
TRU: CASE-1 RG drummed waste	SRS	WIPP	0.089	5.3×10^{-5}	0.075	4.5×10^{-5}	3.0×10^{-8}	0.00014
TRU: CASE-3 WG drummed waste [m]	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	1.7×10^{-8}	0.000095
TRU: CASE-3 WG drummed waste	SRS	WIPP	0.089	5.3×10^{-5}	0.075	4.5×10^{-5}	1.5×10^{-8}	0.00014
TRU: CASE-3 RG drummed waste	INL	WIPP	0.087	5.2×10^{-5}	0.072	4.3×10^{-5}	2.6×10^{-8}	0.000095
TRU: CASE-3 RG drummed waste	SRS	WIPP	0.089	5.3×10^{-5}	0.075	4.5×10^{-5}	2.3×10^{-8}	0.00014
LLW (B-25)-VTR Operation [n]	INL	NNSS	0.026	1.6×10^{-5}	0.017	1.0×10^{-5}	3.3×10^{-10}	0.000055
LLW (B-12)-VTR Operation	INL	NNSS	0.023	1.4×10^{-5}	0.017	1.0×10^{-5}	2.1×10^{-10}	0.000055
LLW (16'-Iso)-VTR Operation	INL	NNSS	0.044	2.7×10^{-5}	0.019	1.2×10^{-5}	5.9×10^{-10}	0.000055
LLW (B-25)-VTR Operation	INL	Energy*Solutions*	0.011	6.2×10^{-6}	0.011	6.4×10^{-6}	3.7×10^{-10}	0.000059
LLW (B-12)-VTR Operation	INL	Energy*Solutions*	0.009	5.4×10^{-6}	0.011	6.4×10^{-6}	2.4×10^{-10}	0.000059
LLW (16'-Iso)-VTR Operation	INL	Energy*Solutions*	0.017	1.0×10^{-5}	0.009	5.3×10^{-6}	7.0×10^{-10}	0.000059
LLW (B-25)-VTR Operation	INL	WCS	0.047	2.8×10^{-5}	0.043	2.6×10^{-5}	9.0×10^{-10}	0.00011
LLW (B-12)-VTR Operation	INL	WCS	0.041	2.5×10^{-5}	0.043	2.6×10^{-5}	5.8×10^{-10}	0.00011
LLW (16'-Iso)-VTR Operation	INL	WCS	0.079	4.8×10^{-5}	0.036	2.2×10^{-5}	1.7×10^{-9}	0.00011
LLW (B-25)-VTR Operation	ORNL	NNSS	0.069	4.2×10^{-5}	0.064	3.9×10^{-5}	6.7×10^{-10}	0.00015
LLW (B-12)-VTR Operation	ORNL	NNSS	0.061	3.6×10^{-5}	0.064	3.9×10^{-5}	4.3×10^{-10}	0.00015
LLW (16'-Iso)-VTR Operation	ORNL	NNSS	0.12	7.0×10^{-5}	0.053	3.2×10^{-5}	4.0×10^{-10}	0.00015
LLW (B-25)-VTR Operation	ORNL	Energy*Solutions*	0.063	3.8×10^{-5}	0.061	3.6×10^{-5}	1.5×10^{-9}	0.00017
LLW (B-12)-VTR Operation	ORNL	Energy*Solutions*	0.055	3.3×10^{-5}	0.061	3.6×10^{-5}	9.8×10^{-10}	0.00017
LLW (16'-Iso)-VTR Operation	ORNL	Energy*Solutions*	0.11	6.4×10^{-5}	0.050	3.0×10^{-5}	2.6×10^{-9}	0.00017
LLW (B-25)-VTR Operation	ORNL	WCS	0.04	2.4×10^{-5}	0.04	2.4×10^{-5}	1.3×10^{-9}	0.00011
LLW (B-12)-VTR Operation	ORNL	WCS	0.035	2.1×10^{-5}	0.04	2.4×10^{-5}	9.2×10^{-10}	0.00011
LLW (16'-Iso)-VTR Operation	ORNL	WCS	0.067	4.0×10^{-5}	0.033	2.0×10^{-5}	2.1×10^{-9}	0.00011
RH-LLW-VTR Operation [o, n]	INL	NNSS	0.03	1.8×10^{-5}	0.037	2.2×10^{-5}	3.7×10^{-11}	0.000055
RH-LLW-VTR Operation	INL	Energy*Solutions*	0.017	1.0×10^{-5}	0.017	1.0×10^{-5}	3.8×10^{-11}	0.000059
RH-LLW-VTR Operation	INL	WCS	0.053	3.2×10^{-5}	0.068	4.1×10^{-5}	8.9×10^{-11}	0.00011
RH-LLW-VTR Operation	ORNL	NNSS	0.078	4.7×10^{-5}	0.10	6.0×10^{-5}	6.9×10^{-11}	0.00015
RH-LLW-VTR Operation	ORNL	Energy*Solutions*	0.071	4.3×10^{-5}	0.095	5.7×10^{-5}	1.8×10^{-10}	0.00017
RH-LLW-VTR Operation	ORNL	WCS	0.045	2.7×10^{-5}	0.062	3.7×10^{-5}	9.7×10^{-11}	0.00011
RH-TRU-VTR Operation [p, n]	INL	WIPP	0.092	5.5×10^{-5}	0.09	5.4×10^{-5}	2.4×10^{-9}	0.000094
RH-TRU-VTR Operation	ORNL	WIPP	0.085	5.1×10^{-5}	0.09	5.4×10^{-5}	2.3×10^{-9}	0.00014
Diluent [q]	DOE site 1	INL	0.004	2.4×10^{-6}	0.009	5.3×10^{-6}	9.8×10^{-9}	0.00019

Material or Wastes	Origin	Transport Destination	Incident-Free				Accident	
			Crew Dose (person-rem)	Crew Risk (LCF)	Population Dose (person-rem)	Population Risk (LCF)	Radiological Risk (LCF)	Non-radiological Risk (traffic fatalities)
Diluent [q]	DOE site 1	SRS	0.001	6.9×10^{-7}	0.002	1.3×10^{-6}	5.0×10^{-9}	0.000065
Diluent [q]	DOE site 2	INL	0.003	2.0×10^{-6}	0.008	4.5×10^{-6}	8.2×10^{-9}	0.00016
Diluent [q]	DOE site 2	SRS	0.001	6.7×10^{-6}	0.002	1.4×10^{-6}	7.4×10^{-9}	0.000053

CASE-1 = aqueous plutonium processing; CASE-3 = pyro-chemical plutonium processing; CCO = criticality control overpack; HEU = highly enriched uranium; JWS= Joint Base Charleston-Weapon Station; LANL = Los Alamos National Laboratory; LCF = latent cancer fatality; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; NFS = Nuclear Fuel Services, Inc.; NNSS = Nevada National Security Site; POC = pipe overpack container; RG = reactor-grade (French) plutonium feed; RH = remote-handled; SRS = Savannah River Site; STA = Secure Transportation Asset; TRU = transuranic; VTR = Versatile Test Reactor; WCS = Waste Control Specialists; WG = weapons-grade plutonium feed; WIPP = Waste Isolation Pilot Plant.

[a] Transported in Type B packages; for analysis purposes, assumed to be shipped in oxide powder form for maximum accident impacts.
[b] Transported by STA.
[c] Transported in 55-gallon drums in 3 TRUPACT-IIs per shipment.
[d] Transported in 55-gallon drums in 3 TRUPACT-IIs per shipment.
[e] Transported in three TRUPACT-IIs per shipment.
[f] Transported in Type A B-25 steel boxes with 5 boxes per shipment; contains fuel fabrication wastes.
[g] MLLW if transported in 55-gallon drums.
[h] The cited values are for the reactor-grade (weapons-grade) fuel.
[i] The plutonium from Europe (France or United Kingdom) will be in 9975 packages within 20-foot ISO containers.
[j] The cited values are for the French (United Kingdom) plutonium accident risks.
[k] It was assumed that the plutonium from France and United Kingdom will be transported from the U.S. port of entry to SRS and then reconfigured and transported to the INL Site.
[L] CASE-1 drummed wastes are cemented wastes in 55-gallon drums, assumed to be 12 drums per shipment, and are in 3 TRUPACT-II for maximizing incident-free population doses.
[m] CASE-3 drummed wastes are metal wastes in 55-gallon drums, assumed to be 28 drums per shipment, and are in 3 TRUPACT-II for maximizing incident free population doses.
[n] The LLW also includes MLLW. All entries with the VTR operation wastes include those generated from the operation of the reactor, its support facilities, and the post-irradiation examination activities. These wastes are transported in a combination of Type A B-25 and B-12 steel boxes with 5 boxes per shipment and in 16-foot ISO containers with 1 container per shipment.
[o] The RH-LLW also includes RH-MLLW. These wastes are transported in a shielded Type B cask. CNS10-160B used as an example.
[p] The RH-TRU also includes RH-MTRU. These wastes are transported in a shielded Type B cask. RH-72B is used.
[q] This material is used to diluent plutonium/uranium-235 waste for transport in CCOs to WIPP. The need is expected to be one shipment every 5 years when the reactor fuel production uses feedstock with no preprocessing activities.

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 (even 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 or commercial vehicle from the accident area (DOE 2002a); 6 hours was assumed for STA shipments. The nonradiological risk factors are for 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 50 miles of 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, risk factors to the truck crew and population for transporting one shipment of plutonium from LANL to SRS are given as 2.0×10^{-5} and 7.4×10^{-5} LCFs, respectively. This risk can also be interpreted as meaning that there is a chance of 2 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 1 in 13,500 that an additional latent fatal cancer could be experienced among the exposed population residing along the transport route due to 1 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–6 shows the annual risks of transporting radioactive materials and wastes under each VTR alternative, and the VTR fuel production options, if the weapons-grade plutonium feedstock were from LANL. **Table E–7** shows the annual risks of transporting radioactive materials and wastes under each VTR alternative, and the VTR fuel production options, if the weapons-grade plutonium feedstock were from SRS. The risks are calculated by multiplying the previously given per-shipment factors by the number of shipments expected to occur in a year and, for radiological doses, by the health risk conversion factors. The number of shipments for the different waste types was calculated using the estimated waste volumes generated during VTR and support facility operations (INL 2020b) and VTR fuel production facility operations (SRNS 2020) and the waste container and shipment characteristics provided in Section E.5.2 and Table E–2. The total annual shipments and associated impacts include transport of VTR fuel assemblies from the fuel production sites under each alternative, of source materials to the fuel production sites, and of generated wastes to the disposal facilities.

Comparison of the results in Tables E–6 and E–7 indicate that the option of fuel production at SRS would generally have higher radiological risk to the population during incident-free transportation than the option of fuel production at INL, due to the greater distances for shipment of the same source (plutonium and uranium) and waste materials. It should be noted that if the weapons-grade plutonium were available at SRS, the annual weapons-grade plutonium-related transports would be lower (about seven shipments), if the VTR fuel production were also at the SRS.

The No Action Alternative, which does not include the installation of VTR facility and its support facilities, would have no additional impacts on the operational facilities at any of the affected sites (i.e., INL, ORNL, and SRS).

Nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks, with an estimate of up to 4 fatalities over all the 60-year operation of VTR if fuel production were to occur at SRS and the INL VTR Alternative were selected. Considering that the transportation activities analyzed in this VTR EIS would occur over about 63 years and the average number of traffic fatalities in the United States over the last 10 years (2008 through 2017 calendar years) is about 34,660 per year (DOT 2019a), the traffic fatality risk under all alternatives would be very small. See Section E.13.5 for further discussion of traffic accident fatality rates.

Table E–6. Annual Risks of Transporting Radioactive Material and Waste Under Each Alternative and Reactor Fuel Production Option (Weapons-Grade Plutonium Feedstock at LANL)[a]

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk [b]	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk [b]	Accident: Radiological Risk [b]	Accident: Non-radiological Risk [b]
No Action Alternative [c]									
All shipments	None	0	0	0	0	0	0	0	0
Total	**Truck**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
INL VTR Alternative									
INL VTR and Support Facility Operations									
Transuranic (CH and RH) waste to WIPP	Truck	0.23 [d]	534	0.02	0.00001	0.02	0.00001	1×10^{-6}	0.00002
Low-level (CH and RH) waste transport									
INL to Energy*Solutions*	Truck	130	66,491	2.1	0.001	1.9	0.001	2×10^{-8}	0.008
INL to NNSS	Truck	130	172,837	3.9	0.002	4.3	0.003	2×10^{-8}	0.007
INL to WCS	Truck	130	307,511	7.0	0.004	7.9	0.005	4×10^{-8}	0.01
Subtotal [e]	**Truck**	**130**	**308,046**	**7.0**	**0.004**	**8.0**	**0.005**	2×10^{-6}	**0.01**
INL VTR Operations plus Reactor Fuel Production Options									
Total 1 = INL VTR/Support Facility Operations plus INL Reactor Fuel Production									
Total 1 – Fab only [f]-WG Pu	**Truck**	**187**	**444,586**	**10.3**	**0.006**	**11.5**	**0.007**	2×10^{-6}	**0.02**
Total 1 – Prep and Fab-WG Pu (Case 1)	**Truck**	**204**	**483,178**	**12.0**	**0.007**	**12.8**	**0.008**	3×10^{-6}	**0.02**
Total 1 – Prep and Fab-WG Pu (Case 3)	**Truck**	**197**	**467,181**	**11.4**	**0.007**	**12.3**	**0.007**	3×10^{-6}	**0.02**
Total 1 – Fab only-RG Pu [g]	**Truck**	**195**	**461,142**	**10.5**	**0.006**	**12.2**	**0.007**	9×10^{-6}	**0.02**
Total 1 – Prep and Fab-RG Pu (Case 1)	**Truck**	**415**	**963,636**	**29.8**	**0.02**	**28.2**	**0.02**	2×10^{-5}	**0.04**
Total 1 – Prep and Fab-RG Pu (Case 3)	**Truck**	**325**	**757,965**	**22.0**	**0.01**	**21.7**	**0.01**	1×10^{-5}	**0.03**
Total 2 = INL VTR/Support Facility Operations plus SRS Reactor Fuel Production									
Total 2 – Fab only-WG Pu	**Truck**	**202**	**520,996**	**11.2**	**0.007**	**12.3**	**0.007**	3×10^{-6}	**0.02**
Total 2 – Prep and Fab-WG Pu (Case 1)	**Truck**	**219**	**550,768**	**12.6**	**0.008**	**13.4**	**0.008**	3×10^{-6}	**0.02**
Total 2 – Prep and Fab-WG Pu (Case 3)	**Truck**	**212**	**534,622**	**11.9**	**0.007**	**12.8**	**0.008**	3×10^{-6}	**0.02**
Total 2 – Fab only-RG Pu	**Truck**	**203**	**503,613**	**11.0**	**0.007**	**11.5**	**0.007**	3×10^{-6}	**0.02**
Total 2 – Prep and Fab-RG Pu (Case 1)	**Truck**	**423**	**1,001,621**	**30.4**	**0.02**	**27.9**	**0.02**	1×10^{-5}	**0.05**
Total 2 – Prep and Fab-RG Pu (Case 3)	**Truck**	**333**	**794,028**	**22.4**	**0.01**	**21.1**	**0.01**	6×10^{-6}	**0.04**
ORNL VTR Alternative									
ORNL VTR and Support Facility Operations									
Transuranic (CH and RH) waste to WIPP	Truck	0.23 [d]	487	0.02	0.00001	0.02	0.00001	2×10^{-6}	0.00003
Low-level (CH and RH) waste transport									

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk [b]	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk [b]	Accident: Radiological Risk [b]	Accident: Non-radiological Risk [b]
ORNL to Energy*Solutions*	Truck	130	408,852	9.3	0.006	11.1	0.007	7×10^{-8}	0.02
ORNL to NNSS	Truck	130	450,619	10.2	0.006	11.7	0.007	2×10^{-8}	0.02
ORNL to WCS	Truck	130	255,208	5.8	0.004	7.3	0.004	5×10^{-8}	0.01
Subtotal [e]	Truck	**130**	**451,106**	**10.2**	**0.006**	**11.8**	**0.007**	**2×10^{-6}**	**0.02**
ORNL VTR Operations plus Reactor Fuel Production Options									
Total 1 = ORNL VTR/Support Facility Operations plus INL Reactor Fuel Production									
Total 1 – Fab only-WG Pu	**Truck**	**202**	**616,966**	**13.2**	**0.008**	**15.0**	**0.009**	**3×10^{-6}**	**0.03**
Total 1 – Prep and Fab-WG Pu (Case 1)	**Truck**	**219**	**676,042**	**15.3**	**0.009**	**16.8**	**0.01**	**3×10^{-6}**	**0.03**
Total 1 – Prep and Fab-WG Pu (Case 3)	**Truck**	**212**	**660,045**	**14.7**	**0.009**	**16.3**	**0.01**	**3×10^{-6}**	**0.03**
Total 1 – Fab only-RG Pu	**Truck**	**210**	**654,006**	**13.8**	**0.008**	**16.2**	**0.01**	**9×10^{-6}**	**0.03**
Total 1 – Prep and Fab-RG Pu (Case 1)	**Truck**	**430**	**1,156,500**	**33.1**	**0.02**	**32.1**	**0.02**	**2×10^{-5}**	**0.05**
Total 1 – Prep and Fab-RG Pu (Case 3)	**Truck**	**340**	**950,829**	**25.3**	**0.02**	**25.7**	**0.02**	**1×10^{-5}**	**0.04**
Total 2 = ORNL VTR/Support Facility Operations plus SRS Reactor Fuel Production									
Total 2 – Fab only-WG Pu	**Truck**	**202**	**617,072**	**14.4**	**0.009**	**15.9**	**0.01**	**3×10^{-6}**	**0.03**
Total 2 – Prep and Fab-WG Pu (Case 1)	**Truck**	**219**	**646,844**	**15.8**	**0.009**	**17.1**	**0.01**	**3×10^{-6}**	**0.03**
Total 2 – Prep and Fab-WG Pu (Case 3)	**Truck**	**212**	**630,698**	**15.1**	**0.009**	**16.5**	**0.01**	**3×10^{-6}**	**0.03**
Total 2 – Fab only-RG Pu	**Truck**	**203**	**599,689**	**14.2**	**0.009**	**15.2**	**0.009**	**3×10^{-6}**	**0.03**
Total 2 – Prep and Fab-RG Pu (Case 1)	**Truck**	**423**	**1,097,697**	**33.6**	**0.02**	**31.5**	**0.02**	**1×10^{-5}**	**0.06**
Total 2 – Prep and Fab-RG Pu (Case 3)	**Truck**	**333**	**890,104**	**25.6**	**0.02**	**24.8**	**0.01**	**6×10^{-6}**	**0.05**
INL Reactor Fuel Production Option									
STA transportation									
All STA routes (with U.S. WG Pu)	STA	13	34,530	0.29	0.0002	0.9	0.0006	5×10^{-7}	0.0007
All STA routes (with European RG Pu) [g]	STA	21	51,086	0.49	0.0003	1.7	0.001	7×10^{-6}	0.001
Low-level waste transport									
INL to NNSS	Truck	15	19,943	0.40	0.0002	0.4	0.0002	2×10^{-9}	0.0008
INL to Energy*Solutions*	Truck	15	7,672	0.15	0.00009	0.2	0.0001	2×10^{-9}	0.0009
INL to WCS	Truck	15	35,482	0.71	0.0004	0.7	0.0004	4×10^{-9}	0.002
Transuranic waste transport									
INL to WIPP (Secondary waste)	Truck	4	9,141	0.35	0.0002	0.3	0.0002	8×10^{-8}	0.0004
INL to WIPP (POCs) Fab only [f]-WG Pu	Truck	13	29,708	1.13	0.0007	0.9	0.0006	2×10^{-7}	0.001
INL to WIPP (diluted PuO_2 in CCOs) [h] – Fab only- WG Pu	Truck	12	27,679	0.87	0.0005	0.7	0.0004	2×10^{-7}	0.001
INL to WIPP (diluted PuO_2 in CCOs) [i] – Fab only-WG Pu	Truck	10	23,530	0.87	0.0005	0.7	0.0004	2×10^{-7}	0.001

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
INL to WIPP – Prep and Fab-WG Pu (Case 1)	Truck	42	95,980	3.65	0.002	3.0	0.002	8×10^{-7}	0.004
INL to WIPP – Prep and Fab-WG Pu (Case 3)	Truck	35	79,983	3.04	0.002	2.5	0.002	5×10^{-7}	0.003
INL to WIPP – Prep and Fab-RG Pu (Case 1)	Truck	245	559,881	21.28	0.01	17.6	0.01	9×10^{-6}	0.02
INL to WIPP – Prep and Fab-RG Pu (Case 3)	Truck	155	354,211	13.47	0.008	11.1	0.007	5×10^{-6}	0.01
Total reactor fuel production transport									
Total – Fab only-WG Pu	**Truck**	**57**	**136,540**	**3.34**	**0.002**	**3.5**	**0.002**	$\mathbf{1 \times 10^{-6}}$	**0.005**
Total – Prep and Fab-WG Pu (Case 1)	**Truck**	**74**	**175,132**	**4.99**	**0.003**	**4.9**	**0.003**	$\mathbf{1 \times 10^{-6}}$	**0.007**
Total – Prep and Fab-WG Pu (Case 3)	**Truck**	**67**	**159,136**	**4.38**	**0.003**	**4.4**	**0.003**	$\mathbf{1 \times 10^{-6}}$	**0.006**
Total – Fab only-RG Pu [g]	**Truck**	**65**	**153,096**	**3.54**	**0.002**	**4.3**	**0.003**	$\mathbf{8 \times 10^{-6}}$	**0.005**
Total – Prep and Fab-RG Pu (Case 1)	**Truck**	**285**	**655,590**	**22.83**	**0.01**	**20.2**	**0.01**	$\mathbf{2 \times 10^{-5}}$	**0.03**
Total – Prep and Fab-RG Pu (Case 3)	**Truck**	**195**	**449,919**	**15.01**	**0.009**	**13.7**	**0.008**	$\mathbf{1 \times 10^{-5}}$	**0.02**
VTR Fuel Assemblies to ORNL	**Truck**	**15**	**49,804**	**0.05**	**0.00003**	**0.2**	**0.0001**	$\mathbf{5 \times 10^{-8}}$	**0.001**
SRS Reactor Fuel Production Option									
STA transportation									
All STA routes (with U.S. WG Pu)	STA	13	21,976	0.3	0.0002	0.9	0.0005	7×10^{-7}	0.0006
All STA routes (with European RG Pu)	STA	14	4,593	0.04	0.00002	0.12	0.00007	5×10^{-7}	0.0001
Low-level waste transport									
SRS to NNSS	Truck	15	58,343	1.2	0.0007	1.1	0.0007	6×10^{-9}	0.003
SRS to Energy*Solutions*	Truck	15	53,578	1.1	0.0006	1.1	0.0007	1×10^{-9}	0.003
SRS to WCS	Truck	15	32,723	0.7	0.0004	0.7	0.0004	6×10^{-10}	0.002
Transuranic waste transport									
SRS to WIPP (secondary waste)	Truck	4	9,226	0.4	0.0002	0.1	0.00005	2×10^{-8}	0.0006
SRS to WIPP (POCs) Fab only [f]-WG Pu	Truck	13	29,986	1.2	0.0007	1.0	0.0006	2×10^{-7}	0.002
SRS to WIPP (diluted PuO_2 in CCOs) [h] – Fab only WG Pu	Truck	12	27,893	0.9	0.0005	0.8	0.0005	2×10^{-7}	0.002
SRS to WIPP (diluted PuO_2 in CCOs) [i] – Fab-WG Pu	Truck	10	23,255	0.9	0.0005	0.8	0.0005	2×10^{-7}	0.001
SRS to WIPP – Prep and Fab-WG Pu (Case 1)	Truck	42	96,876	3.74	0.002	3.15	0.002	8×10^{-7}	0.006
SRS to WIPP – Prep and Fab-WG Pu (Case 3)	Truck	35	80,730	3.06	0.002	2.55	0.002	8×10^{-7}	0.004
SRS to WIPP – Prep and Fab-RG Pu (Case 1)	Truck	245	565,113	21.81	0.01	18.39	0.01	8×10^{-6}	0.03
SRS to WIPP – Prep and Fab-RG Pu (Case 3)	Truck	155	357,520	13.80	0.008	11.63	0.007	4×10^{-6}	0.02
Total reactor fuel production transport									
Total – Fab only-WG Pu	**Truck**	**57**	**156,650**	**4.2**	**0.003**	**4.2**	**0.002**	$\mathbf{2 \times 10^{-6}}$	**0.008**
Total – Prep and Fab-WG Pu (Case 1)	**Truck**	**74**	**186,422**	**5.52**	**0.003**	**5.28**	**0.003**	$\mathbf{2 \times 10^{-6}}$	**0.01**

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free				Accident	
				Crew		Population			
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]	Radiological Risk [b]	Non-radiological Risk [b]
Total – Prep and Fab-WG Pu (Case 3)	**Truck**	**67**	**170,276**	**4.84**	**0.003**	**4.67**	**0.003**	**2×10^{-6}**	**0.008**
Total – Fab only-RG Pu) [g]	**Truck**	**58**	**139,267**	**3.97**	**0.002**	**3.37**	**0.002**	**1×10^{-6}**	**0.008**
Total – Prep and Fab-RG Pu (Case 1)	**Truck**	**278**	**637,275**	**23.37**	**0.01**	**19.73**	**0.01**	**8×10^{-6}**	**0.04**
Total – Prep and Fab-RG Pu (Case 3)	**Truck**	**188**	**429,682**	**15.36**	**0.009**	**12.97**	**0.008**	**5×10^{-6}**	**0.03**
VTR Fuel Assemblies to INL	**Truck**	**15**	**56,300**	**0.06**	**0.00004**	**0.21**	**0.0001**	**6×10^{-8}**	**0.001**
VTR Fuel Assemblies to ORNL	**Truck**	**15**	**9,316**	**0.010**	**0.000006**	**0.041**	**0.00002**	**2×10^{-8}**	**0.0002**

Case 1 = aqueous plutonium processing; Case 3 = pyro-chemical plutonium processing; CCO = criticality control overpack; CH = contact-handled; Fab = fuel fabrication; LANL = Los Alamos National Laboratory; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; POC = pipe overpack container; Prep and Fab = feedstock preparation and fuel fabrication; Pu = plutonium; PuO_2 = plutonium oxide; RG = reactor-grade (European) feed; RH = remote-handled; SRS = Savannah River Site; STA = Secure Transportation Asset; VTR = Versatile Test Reactor; WCS = Waste Control Specialists; WG = weapons-grade feed; WIPP = Waste Isolation Pilot Plant.

[a] For each shipment category, the cited values are annual impact values. The reactor fuel production facilities are to be operational three years before the start of the VTR. The VTR requires about 110 driver fuel assemblies (a full load plus one year of refueling needs) prior to start of operations.

[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). Risks are rounded to one non-zero digit.

[c] Under the No Action Alternative, there would be no new activities and, therefore, no shipments.

[d] Shipments that would occur once every few years are presented as fractional annual shipments.

[e] This subtotal reflects the maximum risk from transporting the LLW/MLLW to NNSS, Energy*Solutions*, or WCS.

[f] Fabrication only is used for the clean weapons-grade plutonium feedstock materials.

[g] Includes impacts from transporting the reactor-grade (European [French or United Kingdom]) plutonium materials, which are assumed to be transported to SRS for repackaging and then transported to INL, if applicable.

[h] Includes impacts from transport of two shipments of adulterants from an assumed distance of 3,000 miles to INL or SRS for dilution of plutonium in CCOs.

[i] Includes impacts from transport of a shipment of diluent from a DOE site (one in 5 years) to INL or SRS for dilution of plutonium in CCOs.

Notes: Totals may differ from the sum of individual entries due to rounding.
All STA routes are the sum of the plutonium and low-enriched uranium transports.
Crew doses are for the truck drivers, assumed to be two drivers for each transport.
To convert kilometers to miles, multiply by 0.6214.
Bolded entries are sums.

Table E–7. Annual Risks of Transporting Radioactive Material and Waste Under Each Alternative and Reactor Fuel Production Option (Weapons-Grade Plutonium Feedstock at SRS)[a]

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk [b]	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk [b]	Accident: Radiological Risk [b]	Accident: Non-radiological Risk [b]
No Action Alternative [c]									
All shipments	None	0	0	0	0	0	0	0	0
Total	**Truck**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
INL VTR Alternative									
INL VTR and Support Facility Operations									
Transuranic (CH and RH) waste to WIPP	Truck	0.23 [d]	534	0.02	0.00001	0.02	0.00001	1×10^{-6}	0.00002
Low-level (CH and RH) waste transport									
INL to Energy*Solutions*	Truck	130	66,491	2.1	0.001	1.9	0.001	2×10^{-8}	0.008
INL to NNSS	Truck	130	172,837	3.9	0.002	4.3	0.003	2×10^{-8}	0.007
INL to WCS	Truck	130	307,511	7.0	0.004	7.9	0.005	4×10^{-8}	0.01
Subtotal [e]	Truck	**130**	**308,046**	**7.0**	**0.004**	**8.0**	**0.005**	**2×10^{-6}**	**0.01**
INL VTR Operations plus Reactor Fuel Production options									
Total 1 = INL VTR/Support Facility Operations plus INL Reactor Fuel Production									
Total 1 – Fab only [f]-WG Pu	**Truck**	**187**	**457,598**	**10.5**	**0.006**	**12,.1**	**0.007**	**3×10^{-6}**	**0.02**
Total 1 – Prep and Fab-WG Pu (Case 1)	**Truck**	**204**	**496,190**	**12.1**	**0.007**	**13.4**	**0.008**	**3×10^{-6}**	**0.02**
Total 1 – Prep and Fab-WG Pu (Case 3)	**Truck**	**197**	**480,193**	**11.5**	**0.007**	**12.9**	**0.007**	**3×10^{-6}**	**0.02**
Total 1 – Fab only-RG Pu [g]	**Truck**	**195**	**461,142**	**10.5**	**0.006**	**12.2**	**0.007**	**9×10^{-6}**	**0.02**
Total 1 – Prep and Fab-RG Pu (Case 1)	**Truck**	**415**	**963,636**	**29.8**	**0.02**	**28.2**	**0.02**	**2×10^{-5}**	**0.04**
Total 1 – Prep and Fab-RG Pu (Case 3)	**Truck**	**325**	**757,965**	**22.0**	**0.01**	**21.7**	**0.01**	**1×10^{-5}**	**0.03**
Total 2 = INL VTR/Support Facility Operations plus SRS Reactor Fuel Production									
Total 2 – Fab only-WG Pu	**Truck**	**197**	**501,945**	**11.0**	**0.007**	**11.5**	**0.007**	**2×10^{-6}**	**0.02**
Total 2 – Prep and Fab-WG Pu (Case 1)	**Truck**	**212**	**531,717**	**12.3**	**0.008**	**12.6**	**0.008**	**2×10^{-6}**	**0.02**
Total 2 – Prep and Fab-WG Pu (Case 3)	**Truck**	**205**	**515,571**	**11.6**	**0.007**	**12.0**	**0.008**	**2×10^{-6}**	**0.02**
Total 2 – Fab only-RG Pu	**Truck**	**203**	**503,613**	**11.0**	**0.007**	**11.5**	**0.007**	**3×10^{-6}**	**0.02**
Total 2 – Prep and Fab-RG Pu (Case 1)	**Truck**	**423**	**1,001,621**	**30.4**	**0.02**	**27.9**	**0.02**	**1×10^{-5}**	**0.05**
Total 2 – Prep and Fab-RG Pu (Case 3)	**Truck**	**333**	**794,028**	**22.4**	**0.01**	**21.1**	**0.01**	**6×10^{-6}**	**0.04**
ORNL VTR Alternative									
ORNL VTR and Support Facility Operations									
Transuranic (CH and RH) waste to WIPP	Truck	0.23 [d]	487	0.02	0.00001	0.02	0.00001	2×10^{-6}	0.00003
Low-level (CH and RH) waste transport									
ORNL to Energy*Solutions*	Truck	130	408,852	9.3	0.006	11.1	0.007	7×10^{-8}	0.02
ORNL to NNSS	Truck	130	450,619	10.2	0.006	11.7	0.007	2×10^{-8}	0.02

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk [b]	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk [b]	Accident: Radiological Risk [b]	Accident: Non-radiological Risk [b]
ORNL to WCS	Truck	130	255,208	5.8	0.004	7.3	0.004	5×10^{-8}	0.01
Subtotal [e]	Truck	**130**	**451,106**	**10.2**	**0.006**	**11.8**	**0.007**	$\mathbf{2 \times 10^{-6}}$	**0.02**
ORNL VTR Operations plus Reactor Fuel Production Options									
Total 1 = ORNL VTR/Support Facility Operations plus INL Reactor Fuel Production									
Total 1 – Fab only-WG Pu	**Truck**	**202**	**650,461**	**13.8**	**0.008**	**16.1**	**0.01**	$\mathbf{3 \times 10^{-6}}$	**0.03**
Total 1 – Prep and Fab-WG Pu (Case 1)	**Truck**	**219**	**689,054**	**15.4**	**0.009**	**17.4**	**0.01**	$\mathbf{4 \times 10^{-6}}$	**0.03**
Total 1 – Prep and Fab-WG Pu (Case 3)	**Truck**	**212**	**673,057**	**14.8**	**0.009**	**16.9**	**0.01**	$\mathbf{3 \times 10^{-6}}$	**0.03**
Total 1 – Fab only-RG Pu	**Truck**	**210**	**654,006**	**13.8**	**0.008**	**16.2**	**0.01**	$\mathbf{9 \times 10^{-6}}$	**0.03**
Total 1 – Prep and Fab-RG Pu (Case 1)	**Truck**	**430**	**1,156,500**	**33.1**	**0.02**	**32.1**	**0.02**	$\mathbf{2 \times 10^{-5}}$	**0.05**
Total 1 – Prep and Fab-RG Pu (Case 3)	**Truck**	**340**	**950,829**	**25.3**	**0.02**	**25.7**	**0.02**	$\mathbf{1 \times 10^{-5}}$	**0.04**
Total 2 = ORNL VTR/Support Facility Operations plus SRS Reactor Fuel Production									
Total 2 – Fab only-WG Pu	**Truck**	**195**	**598,021**	**13.8**	**0.008**	**16.1**	**0.01**	$\mathbf{3 \times 10^{-6}}$	**0.03**
Total 2 – Prep and Fab-WG Pu (Case 1)	**Truck**	**212**	**627,793**	**15.5**	**0.009**	**16.2**	**0.01**	$\mathbf{2 \times 10^{-6}}$	**0.03**
Total 2 – Prep and Fab-WG Pu (Case 3)	**Truck**	**205**	**611,647**	**14.9**	**0.009**	**15.6**	**0.009**	$\mathbf{2 \times 10^{-6}}$	**0.03**
Total 2 – Fab only-RG Pu	**Truck**	**203**	**599,689**	**14.2**	**0.009**	**15.2**	**0.009**	$\mathbf{3 \times 10^{-6}}$	**0.03**
Total 2 – Prep and Fab-RG Pu (Case 1)	**Truck**	**423**	**1,097,697**	**33.6**	**0.02**	**31.5**	**0.02**	$\mathbf{1 \times 10^{-5}}$	**0.06**
Total 2 – Prep and Fab-RG Pu (Case 3)	**Truck**	**333**	**890,104**	**25.6**	**0.02**	**24.8**	**0.01**	$\mathbf{6 \times 10^{-6}}$	**0.05**
INL Reactor Fuel Production Option									
STA transportation									
All STA routes (with U.S. WG Pu)	STA	13	47,542	0.45	0.0003	1.5	0.0009	1×10^{-6}	0.0009
All STA routes (with European RG Pu) [g]	STA	21	51,086	0.49	0.0003	1.7	0.001	7×10^{-6}	0.001
Low-level waste transport									
INL to NNSS	Truck	15	19,943	0.40	0.0002	0.4	0.0002	2×10^{-9}	0.0008
INL to Energy*Solutions*	Truck	15	7,672	0.15	0.00009	0.2	0.0001	2×10^{-9}	0.0009
INL to WCS	Truck	15	35,482	0.71	0.0004	0.7	0.0004	4×10^{-9}	0.002
Transuranic waste transport									
INL to WIPP (Secondary waste)	Truck	4	9,141	0.35	0.0002	0.3	0.0002	8×10^{-8}	0.0004
INL to WIPP (POCs) Fab only [f]-WG Pu	Truck	13	29,708	1.13	0.0007	0.9	0.0006	2×10^{-7}	0.001
INL to WIPP (diluted PuO_2 in CCOs) [h] – Fab only- WG Pu	Truck	12	27,679	0.87	0.0005	0.7	0.0004	2×10^{-7}	0.001
INL to WIPP (diluted PuO_2 in CCOs) [i] – Fab only-WG Pu	Truck	10	23,530	0.87	0.0005	0.7	0.0004	2×10^{-7}	0.001
INL to WIPP – Prep and Fab-WG Pu (Case 1)	Truck	42	95,980	3.65	0.002	3.0	0.002	8×10^{-7}	0.004
INL to WIPP – Prep and Fab-WG Pu (Case 3)	Truck	35	79,983	3.04	0.002	2.5	0.002	5×10^{-7}	0.003
INL to WIPP – Prep and Fab-RG Pu (Case 1)	Truck	245	559,881	21.28	0.01	17.6	0.01	9×10^{-6}	0.02
INL to WIPP – Prep and Fab-RG Pu (Case 3)	Truck	155	354,211	13.47	0.008	11.1	0.007	5×10^{-6}	0.01

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free: Crew Dose (person-rem)	Incident-Free: Crew Risk [b]	Incident-Free: Population Dose (person-rem)	Incident-Free: Population Risk [b]	Accident: Radiological Risk [b]	Accident: Non-radiological Risk [b]
Total reactor fuel production transport									
Total – Fab only-WG Pu	**Truck**	**57**	**149,552**	**3.50**	**0.002**	**4.1**	**0.002**	**1×10^{-6}**	**0.005**
Total – Prep and Fab-WG Pu (Case 1)	**Truck**	**74**	**188,144**	**5.15**	**0.003**	**5.5**	**0.003**	**2×10^{-6}**	**0.007**
Total – Prep and Fab-WG Pu (Case 3)	**Truck**	**67**	**172,148**	**4.54**	**0.003**	**5.0**	**0.003**	**2×10^{-6}**	**0.006**
Total – Fab only-RG Pu [g]	**Truck**	**65**	**153,096**	**3.54**	**0.002**	**4.3**	**0.003**	**8×10^{-6}**	**0.005**
Total – Prep and Fab-RG Pu (Case 1)	**Truck**	**285**	**655,590**	**22.83**	**0.01**	**20.2**	**0.01**	**2×10^{-5}**	**0.03**
Total – Prep and Fab-RG Pu (Case 3)	**Truck**	**195**	**449,919**	**15.01**	**0.009**	**13.7**	**0.008**	**1×10^{-5}**	**0.02**
VTR Fuel Assemblies to ORNL	**Truck**	**15**	**49,804**	**0.05**	**0.00003**	**0.2**	**0.0001**	**5×10^{-8}**	**0.001**
SRS Reactor Fuel Production Option									
STA transportation									
All STA routes (with U.S. WG Pu)	STA	6	2,925	0.02	0.00001	0.1	0.00003	4×10^{-10}	0.00008
All STA routes (with European RG Pu)	STA	14	4,593	0.04	0.00002	0.12	0.00007	5×10^{-7}	0.0001
Low-level waste transport									
SRS to NNSS	Truck	15	58,343	1.2	0.0007	1.1	0.0007	6×10^{-9}	0.003
SRS to Energy*Solutions*	Truck	15	53,578	1.1	0.0006	1.1	0.0007	1×10^{-9}	0.003
SRS to WCS	Truck	15	32,723	0.7	0.0004	0.7	0.0004	6×10^{-10}	0.002
Transuranic waste transport									
SRS to WIPP (secondary waste)	Truck	4	9,226	0.4	0.0002	0.1	0.00005	2×10^{-8}	0.0006
SRS to WIPP (POCs) Fab only [f]-WG Pu	Truck	13	29,986	1.2	0.0007	1.0	0.0006	2×10^{-7}	0.002
SRS to WIPP (diluted PuO_2 in CCOs) [h] – Fab only WG Pu	Truck	12	27,893	0.9	0.0005	0.8	0.0005	2×10^{-7}	0.002
SRS to WIPP (diluted PuO_2 in CCOs) [i] – Fab-WG Pu	Truck	10	23,255	0.9	0.0005	0.8	0.0005	2×10^{-7}	0.001
SRS to WIPP – Prep and Fab-WG Pu (Case 1)	Truck	42	96,876	3.74	0.002	3.15	0.002	8×10^{-7}	0.006
SRS to WIPP – Prep and Fab-WG Pu (Case 3)	Truck	35	80,730	3.06	0.002	2.55	0.002	8×10^{-7}	0.004
SRS to WIPP – Prep and Fab-RG Pu (Case 1)	Truck	245	565,113	21.81	0.01	18.39	0.01	8×10^{-6}	0.03
SRS to WIPP – Prep and Fab-RG Pu (Case 3)	Truck	155	357,520	13.80	0.008	11.63	0.007	4×10^{-6}	0.02
Total reactor fuel production transport									
Total – Fab only-WG Pu	**Truck**	**50**	**137,599**	**3.90**	**0.002**	**3.30**	**0.002**	**9×10^{-7}**	**0.008**
Total – Prep and Fab-WG Pu (Case 1)	**Truck**	**67**	**167,371**	**5.28**	**0.003**	**4.42**	**0.003**	**8×10^{-7}**	**0.009**
Total – Prep and Fab-WG Pu (Case 3)	**Truck**	**60**	**151,225**	**4.61**	**0.003**	**3.82**	**0.002**	**8×10^{-7}**	**0.007**
Total – Fab only-RG Pu) [g]	**Truck**	**58**	**139,267**	**3.97**	**0.002**	**3.37**	**0.002**	**1×10^{-6}**	**0.008**
Total – Prep and Fab-RG Pu (Case 1)	**Truck**	**278**	**637,275**	**23.37**	**0.01**	**19.73**	**0.01**	**8×10^{-6}**	**0.04**
Total – Prep and Fab-RG Pu (Case 3)	**Truck**	**188**	**429,682**	**15.36**	**0.009**	**12.97**	**0.008**	**5×10^{-6}**	**0.03**
VTR Fuel Assemblies to INL	**Truck**	**15**	**56,300**	**0.06**	**0.00004**	**0.21**	**0.0001**	**6×10^{-8}**	**0.001**
VTR Fuel Assemblies to ORNL	**Truck**	**15**	**9,316**	**0.010**	**0.000006**	**0.041**	**0.00002**	**2×10^{-8}**	**0.0002**

Route	Transport Mode	Number of Shipments	One-way Kilometers Traveled	Incident-Free				Accident	
				Crew		Population		Radiological Risk [b]	Non-radiological Risk [b]
				Dose (person-rem)	Risk [b]	Dose (person-rem)	Risk [b]		

Case 1 = aqueous plutonium processing; Case 3 = pyro-chemical plutonium processing; CCO = criticality control overpack; CH = contact-handled; Fab = fuel fabrication; INL= Idaho National Laboratory; NNSS = Nevada National Security Site; ORNL = Oak Ridge National Laboratory; POC = pipe overpack container; Pu = plutonium; PuO_2 = plutonium oxide; Prep and Fab = feedstock preparation (processing) and fuel fabrication; RG = reactor-grade (European) feed; RH = remote-handled; SRS = Savannah River Site; STA = Secure Transportation Asset; VTR = Versatile Test Reactor; WCS = Waste Control Specialists; WG = weapons-grade feed; WIPP = Waste Isolation Pilot Plant.

[a] For each shipment category, the cited values are annual impact values. The reactor fuel production facilities are to be operational three years before the start of the VTR. The VTR requires about 110 driver fuel assemblies (a full load plus 1 year of refueling needs) prior to start of operations.

[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). Risks are rounded to one non-zero digit.

[c] Under the No Action Alternative, there would be no new activities and, therefore, no shipments.

[d] Shipments that would occur once every few years are presented as fractional annual shipments.

[e] This subtotal reflects the maximum risk from transporting the LLW/MLLW to NNSS, Energy*Solutions*, or WCS.

[f] Fabrication only is used for the clean weapons-grade plutonium feed materials.

[g] Includes impacts from transporting the reactor-grade (European [French or United Kingdom]) plutonium materials, which are assumed to be transported to SRS for repackaging and then transported to INL, if applicable.

[h] Includes impacts from transport of two shipments of adulterants from an assumed distance of 3,000 miles to INL or SRS for dilution of plutonium in CCOs.

[i] Includes impacts from transport of a shipment of diluent from a DOE site (1 in 5 years) to INL or SRS for dilution of plutonium in CCOs.

Notes: Totals may differ from the sum of individual entries due to rounding.
All STA routes are the sum of the plutonium and low-enriched uranium transports.
Crew doses are for the truck drivers. Analysis assumed two drivers for each transport.
To convert kilometers to miles, multiply by 0.6214.
Bolded entries are sums.

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–8**, considering all shipment types. Doses are presented on a per-event basis (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 RH-low-level radioactive waste for 1 hour is calculated to be 0.024 rem (24 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 0.028 rem (or 28 millirem) per hour if the inspector stood within about 3.3 feet of the cargo for the duration of the inspection.

A member of the public living along the route would likely receive multiple exposures from passing shipments during the period analyzed. The cumulative dose to this resident is calculated by assuming all the 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 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–8 applies to all radioactive transport types, then the maximum dose to this resident (if all the materials were shipped via this route [a total of 430 shipments]) would be about 0.14 millirem annually, with a risk of developing an LCF of about 8.3×10^{-8}. This corresponds to the maximum annual dose that would occur for truck shipments under the ORNL VTR Alternative, which includes an estimated 430 shipments per year.

Table E–8. 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	0.028 rem per event per hour of inspection
Public	
Resident (along the truck route)	3.2×10^{-7} rem per event
Person in traffic congestion	0.012 rem per event per half an hour stop
Person at a rest stop/gas station	0.0002 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 2017a). Based on the number of commercial shipments and the total crew dose to two drivers in Tables E–6 and E–7, a commercial driver dose would not exceed this administrative control limit. Therefore, the administrative control limit is reflected in this table for the maximally exposed truck crew member.

The accident risk assessment and the impacts shown in Tables E–6 and E–7 take 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 an 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 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 2.2 miles per hour is assumed.
- The population is assumed to have a uniform density to a radius 50 miles and to be exposed to the entire plume passage. A neutral weather condition (Pasquill Stability Class D) with a wind speed of 8.8 miles per hour is assumed. Because the consequence is proportional to the population density, the accident is first assumed to occur in an urban[5] 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–9 provides the estimated dose and potential LCFs that could result for an individual and population from a maximum reasonably foreseeable truck transportation accident with the highest consequences under each alternative. (Only those accidents with a probability greater than 1×10^{-7} per year are analyzed.) The accident is assumed to involve a severe impact (collision) in conjunction with a long-duration fire. The highest consequences for the maximum reasonably foreseeable accident based on population dose are from transportation accidents occurring in a rural area involving weapons-grade plutonium oxide powder from LANL to SRS and in a suburban area involving reactor-grade (European fuel) plutonium oxide powder from SRS to INL.

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. The risks from transporting the construction and nonradiological wastes are estimated in terms of the number of traffic fatalities. For construction materials, it was assumed that materials would be transported 62 miles one way. Hazardous wastes were assumed to be transported about 1,240 miles. The truck accident and fatality rates that were assumed for construction materials were based on the State-level accident and fatality data with appropriate corrections for missing information) (Saricks and Tompkins 1999; UMTRI 2003). This assumption leads to truck accident and fatality rates of 7.69 accidents per 10 million truck-kilometers travelled and 4.08 fatalities per 100 million truck-kilometers travelled for SRS, 6.45 accidents per 10 million truck-kilometers travelled and 3.83 fatalities per 100 million truck-kilometers travelled for INL, and 2.61 accidents per 10 million truck-kilometers travelled and 2.0 fatalities per 100 million truck-kilometers travelled for ORNL, respectively. The truck accident and fatality rates 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.

[5] 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, and if that also has a likelihood of less than 1-in-10 million per year, then the accident is evaluated for a rural area.

Table E–9. Estimated Dose to the Population and to Maximally Exposed Individuals Under the Maximum Reasonably Foreseeable Accident

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]	*Population* [b]		*MEI* [c]	
					Dose (person-rem)	*LCF*	*Dose (rem)*	*LCF*
Truck transport to WIPP [d]	Secondary TRU waste in a TRUPACT II-WG (RG)	All	2.1×10^{-7} to 4.8×10^{-7}	Suburban	1.8 (5.7)	1×10^{-3} (3×10^{-3})	0.001 (0.005)	6×10^{-7} (3×10^{-6})
Truck transport to WIPP [e]	Processed plutonium as TRU waste in POCs- WG (RG)	All	2.4×10^{-7} to 6.7×10^{-7}	Suburban	13.8 (86.2)	8×10^{-3} (5×10^{-2})	0.0075 (0.072)	5×10^{-6} (4×10^{-5})
Truck transport to VTR facilities [f]	VTR fuel assemblies-WG (RG)	All	1.8×10^{-7} to 8.7×10^{-6}	Suburban	48.2 (245)	0.03 (0.15)	0.03 (0.17)	2×10^{-5} (1×10^{-4})
Truck transport to disposal sites [g]	LLW in B-25s	All	2.0×10^{-7} to 6.9×10^{-6}	Suburban	0.033	2×10^{-5}	0.00001	7×10^{-9}
Truck transport to WIPP [g]	Processed TRU waste in CCOs –WG (RG)	All	1.8×10^{-7} to 5.2×10^{-7}	Suburban	27.6 (172)	0.017 (0.10)	0.015 (0.14)	9×10^{-6} (9×10^{-5})
STA transport to SRS or INL [h]	Plutonium (in oxide powder) in a Type B package- WG (RG)	All	1.2×10^{-7} to 2.5×10^{-6}	Rural (Suburban)	348 (61,500)	0.21 (37)	4.3 (21.2)	3×10^{-3} (1×10^{-2})
Truck transport to SRS or INL [i]	Diluent for diluting plutonium waste	All	2.4×10^{-7} to 2.7×10^{-7}	Rural	0.076	5×10^{-5}	0.006	4×10^{-6}

CCO = criticality control overpack; INL= Idaho National Laboratory; LCF = latent cancer fatality; LLW = low-level radioactive waste; MEI = maximally exposed individual; NNSS = Nevada National Security Site; POC = pipe overpack container; RG = reactor-grade plutonium; SRS = Savannah River Site; STA = safeguards transporter; TRU = transuranic; TRUPACT-II = Transuranic Package Transporter Model 2; VTR=Versatile Test Reactor; WG = weapons-grade plutonium; 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 50 miles. The weather condition was assumed to be Pasquill Stability Class D with a wind speed of 8.8 miles per hour.

[c] The MEI is assumed to be 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 2.2 miles per hour.

[d] While these shipments would occur under all alternatives, the likelihood of an accident in a rural area (from INL) is greater than that in suburban area (from SRS). However, the accident for transport to WIPP from SRS has a larger population dose and risk, as indicated here.

[e] While these shipments would occur under all alternatives and even though the consequences of an accident are larger for shipments from INL than for shipments from SRS, the likelihood of an accident in a suburban area from SRS transport is greater than that from INL. Therefore, the transport from SRS would lead to a larger population risk, as indicated here.

[f] While these shipments would occur under all alternatives and even though the likelihood of an accident is greater for shipments from INL to ORNL than for shipments from SRS to INL or ORNL, the consequences of an accident in a suburban area for the SRS to INL route are larger than those from the other routes, leading to a larger population risk. Therefore, the transport from SRS to INL is indicated here.

[g] While these shipments would occur under all alternatives and even though the consequences of an accident is are larger for shipments from INL to WCS than for shipments from SRS to any disposal sites, the likelihood of an accident in a suburban area from SRS to Energy*Solutions* transport is greater than that from INL to any disposal sites. Therefore, the transport from SRS to Energy*Solutions* would lead to a larger population risk, as indicated here.

[h] While these shipments would occur under all alternatives, the likelihood of an accident in a rural area from transport from LANL to SRS is greater than that for transport to INL. [The likelihood of an accident in a rural area from LANL to INL transport is 1.9×10^{-6} per year, with a population dose consequence of 286 person-rem.] However, the population risk is higher when the plutonium is a reactor-grade (French) with the likelihood of an accident in a suburban area of 1.2×10^{-7} per year. Therefore, the transport to INL from SRS for the INL VTR fuel production option would lead to a larger population risk, as indicated here.

[i] Shipments of diluents to INL or SRS originates from two DOE sites. While these shipments would occur under all alternatives, the likelihood of an accident in a rural area to INL is greater would greater than one in 10 million (e.g., 1.0×10^{-7} per year). The likelihood of an accident on either route to SRS is less than one in 10 million. Therefore, transport along the route to INL with the greater likelihood of an accident would lead to a larger population risk, as indicated here.

Table E–10 summarizes the impacts in terms of total number of kilometers, accidents, and fatalities for the VTR alternatives and reactor fuel production options. The results indicate that there would be a smaller risk of traffic accidents and fatalities for the INL VTR Alternative that uses the existing facilities to support the VTR operation than for the ORNL VTR Alternative. For the ORNL VTR alternative, additional support facilities have to be constructed. The construction impacts of the needed support facilities would be about 30 percent of the VTR construction impacts (Leidos 2020).

Table E–10. Estimated Impacts of Construction Material and Hazardous Waste Transport

Materials	*Number of Shipments*	*Total Distance Traveled (kilometers; two-way)*	*Number of Accidents*	*Number of Fatalities*
INL VTR Alternative				
Construction	17,635	23,928,500	1.4×10^{1}	6×10^{-1}
Hazardous Wastes	115	230,000	1.3×10^{-1}	5×10^{-3}
Total	17,750	24,158,500	1.4×10^{1}	6×10^{-1}
ORNL VTR Alternative				
Construction	22,930	31,107,100	1.7×10^{1}	7×10^{-1}
Hazardous Wastes	150	299,000	1.7×10^{-1}	7×10^{-3}
Total	23,075	31,406,050	1.7×10^{1}	7×10^{-1}
INL Fuel Production Option[a]				
Construction	0.0			
Hazardous Wastes	0.0			
SRS Fuel Production Option				
Construction	1,227	245,400	1.9×10^{-1}	1.0×10^{-2}
Hazardous Wastes	1,227	245,400	1.9×10^{-1}	1.0×10^{-2}
Spent Fuel Storage Pad				
INL VTR Alternative	711	142,000	9.2×10^{-2}	6×10^{-3}
ORNL VTR Alternative	711	142,000	3.7×10^{-2}	3×10^{-3}

INL= Idaho National Laboratory; ORNL = Oak Ridge National Laboratory; SRS = Savannah River Site; VTR = Versatile Test Reactor.

[a] INL existing facilities do not require major construction to accommodate the equipment (e.g., glove boxes) for the fuel production activities.

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

Source: INL 2020c; Leidos 2020; SRNS 2020.

E.10 Onsite Transports

Onsite shipment of radioactive materials and wastes would occur at the SRS, INL, and ORNL. These shipments would not have any substantial effect on members of the public because roads between the site processing areas are closed to the public or have comparatively short distances to which the public has access. The onsite waste shipments from construction and operations evaluated in this EIS would be a small fraction of the overall site waste shipments.

E.11 Conclusions

Based on the results presented in the previous sections, the following conclusions have been reached (see Tables E–6 and E–7):

- For all alternatives, the transportation of radioactive material and waste likely would result in no additional fatalities as a result of radiation, either from incident-free operation or postulated transportation accidents.
- The highest annual risk to the public due to incident-free transportation would be under the ORNL VTR Alternative with the INL Reactor Fuel Production Options, where up to 430 truck shipments of radioactive materials, wastes, and VTR fuel assemblies would be transported annually.
- The nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) are greater than the radiological accident risks.
- Under both VTR alternatives, up to four traffic fatalities would be expected over the duration of the activities (which is assumed to be 63 years, 60 years of VTR operation and 3 additional years of fuel production prior to VTR operation). For comparison, in the United States in 2017

there were over 37,133 traffic fatalities due to all vehicular crashes (DOT 2019a). The incremental increase in risk to the general population from shipments associated with the VTR program would, therefore, be very small and would not substantially contribute to cumulative impacts.

E.12 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. The cumulative impacts information data in the Yucca EIS was updated in the 2015 *Surplus Plutonium Disposition (SPD) Supplemental EIS* (DOE 2015a), and is further updated to include the current information on various activities. The timeframe of the SPD Supplemental EIS transportation impacts analysis began in 1943 and extended to 2073. The time frame for this VTR EIS analysis is for 63 years beyond the 2028 start of VTR operation, which extends the cumulative impact period beyond 2090.

Table E–11 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 VTR EIS; historical, reasonably foreseeable actions; and general transportation) was estimated to be about 430,000 person-rem (about 258 LCFs). The total general population collective dose was estimated to be about 441,000 person-rem (about 265 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 2091 is about 525, or an average of about 4 LCFs per year. Over this same period (about 148 years), approximately 88 million people would have died from cancer, based on National Center for Health Statistics data. The annual number of cancer deaths in the United States in 2017 was about 599,000 (CDC 2019) with about a 3 percent fluctuation in the number of cancer fatalities from 1 year to the next, over the last previous 10 years (2008 through 2017), and a mean of 584,000 cancer fatalities per year. The transportation-related LCFs would be 0.0006 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.

E.13 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 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. There are also uncertainties 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 the calculations themselves (e.g., approximate algorithms used within the computer codes).

Table E–11. Cumulative Transportation-Related Radiological Collective Doses and Latent Cancer Fatalities

Category	***Collective Worker Dose (person-rem)***	***Collective General Population Dose (person-rem)***
Historical [a]	49	25
Past, Present, and Reasonably Foreseeable Future Actions (DOE) [a, b]	29,600	36,700
Additional Reasonably Foreseeable Future Actions (DOE)		
Permanent Disposal or Interim Storage of Spent Nuclear Fuel [c]	5,600–5,900	1,100–1,200
Final Greater-Than-Class C EIS [d]	180	68
Final SEIS for the Disposition of Du Oxides Conversion Product [l]	145–276	217–723
SRS Pit Production EIS [m]	581–901	334–455
SPD SEIS Proposed Action [n]	230–650	150–580
WIPP Supplemental Analysis [e]	492	383
Production of Tritium in a Commercial Light Water Reactor [f]	25–60	2.7–12
Liquid Highly Enriched Uranium Shipments from Canada [g]	17	10
Santa Susana Field Laboratory Remediation [h]	3.0	0.89
Acceptance and Disposition of Spent Nuclear Fuel from the Federal Republic of Germany [i]	0.12–10.9	0.54–4.7
Sister Rod Shipments [j]	0.27	0.75
Total Past, Present, and Reasonably Foreseeable Future Actions (DOE)	36,900–38,100	38,900–40,100
Past, Present, and Reasonably Foreseeable Future Actions (non-DOE) [a]	5,380	61,300
General Radioactive Materials Transportation [a]	384,000	338,000
Transportation Impacts in this VTR EIS [k]		
INL VTR Alternative	*624–1,915*	*699–1,777*
ORNL VTR Alternative	*832–2,117*	*945–2,022*
Total [o]	**427,000–430,000**	**439,000–441,000**
Total Latent Cancer Fatalities [p]	256–258	263–265

[a] DOE 2015a:Table 4-48, p. 4-136 and 4-137. Historical shipments are shipments that occurred in the past.
[b] DOE 2015a:Table 4-48, p. 4-136 and 4-137. Excluding the doses from shipping in the draft Greater-Than-Class C Waste EIS and the DUF6 Conversion at Paducah and Portsmouth EISs.
[c] DOE 2008b:Table 8-14, p. 8-44. For the purposes of the transportation cumulative impacts analysis, DOE considered the Yucca Mountain, Nevada, repository site as a surrogate destination for an interim storage facility or a permanent repository.
[d] DOE 2016a:Table 4.3.9-1, p. 4-68 and 4-69; DOE 2018a:3-20.
[e] DOE 2009:Table 2, p. 5.
[f] DOE 2016b:Table F-12, p. F-17. Calculated from LCFs.
[g] DOE 2013:A-11. Calculated from LCFs.
[h] DOE 2018b:Table H-9, p. H-31.
[i] DOE 2017b:Table 4-28, p. 4-68.
[j] DOE 2015b:Table 3-1, p. 24. Calculated from LCFs.
[k] From Section E.8 (Table E-6) of Appendix E, and adjusted for the 63 years of cumulative operations in this VTR EIS.
[l] DOE 2020b:Table 4-51, p 4-93. The highest disposal option impacts for rail and truck shipments.
[m] DOE 2020a:Table 5-7, for 50–80 pits per year; 50 years of operation.
[n] DOE 2015a:Table E-20; this addition is a conservative assumption as the range of alternatives in this SEIS are not implemented. The impacts of transporting surplus pits from Pantex to SRS or LANL for disassembly and related activities are a fraction of values presented here.
[o] Total values are rounded to three significant figures. (Note: the lower end of the range totals includes the lowest value from the VTR alternatives; the upper end of the range includes the highest value.)
[p] Total LCFs are calculated assuming 0.0006 LCFs per person-rem of exposure (DOE 2003b).

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.13.1 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 and E–7 are believed to represent unbiased, reasonably accurate estimates from current information in terms of relative risk comparisons.

E.13.2 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 VTR 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.13.3 Uncertainties in Route Determination

Analyzed routes have been determined between all origin and destination sites considered in this VTR 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 VTR EIS.

E.13.4 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.13.5 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, 2019b).

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