DOE/EIS-0279-SA-01
DOE/EIS-0218-SA-06

Supplement Analysis

Savannah River Site
Spent Nuclear Fuel Management

U.S. Department of Energy
Office of Environmental Management
Savannah River Operations Office
Aiken, South Carolina

March 2013

SUPPLEMENT ANALYSIS
SAVANNAH RIVER SITE SPENT NUCLEAR FUEL MANAGEMENT
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1. INTRODUCTION

The Department of Energy (DOE) has a continuing responsibility for safeguarding and managing highly enriched uranium[1] (HEU), including that found in existing and projected quantities of spent nuclear fuel (SNF) managed by DOE's Savannah River Site (SRS). DOE has prepared three reviews pursuant to the National Environmental Policy Act (NEPA) related to SNF management at SRS:

(1) The *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement* (SNF PEIS) (DOE/EIS-0203; DOE, 1995a) evaluated alternatives for management of SNF for which DOE is responsible, including production reactor fuel, Naval reactor fuel, and domestic and foreign research reactor fuel;

(2) The *Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel Environmental Impact Statement* (FRR EIS) (DOE/EIS-0218; DOE, 1996a), which is tiered from the SNF PEIS, evaluated alternatives for return to the United States for storage and disposition of SNF and target material[2] containing uranium enriched in the United States and supplied to foreign countries; and

(3) The *Savannah River Site Spent Nuclear Fuel Management Environmental Impact Statement* (SRS SNF EIS) (DOE/EIS-0279; DOE, 2000a) evaluated alternatives for storage and disposition of SNF and target material that SRS manages. The SRS SNF EIS is tiered from both the SNF PEIS and the FRR EIS.

Over the years, DOE has taken many of the actions described in Records of Decision (RODs) based on the above EISs. However, DOE has not implemented its decision to develop and operate a melt and dilute technology for aluminum-clad SNF, as announced in the SRS SNF ROD (DOE, 2000b). Due to technical issues involving the off-gas system and funding limitations, DOE did not advance the melt and dilute technology beyond the research and development stage. DOE now proposes to change the management method for up to approximately 3.3 metric tons of heavy metal (MTHM) of aluminum-clad SNF from melt and dilute to conventional processing in H-Canyon at SRS and to down-blend the resultant HEU to low enriched uranium (LEU) for use in commercial nuclear reactor fuel. The potential

[1] HEU is uranium enriched in the fissile isotope U-235 to a level of 20 percent or greater.
[2] Targets are radioactive materials placed inside a nuclear reactor to produce particular radioisotopes. Target materials are residual materials left after the desired radioisotopes have been removed from the targets. For example, the Group D target materials discussed in this SA are residual materials from the production in a research reactor of molybdenum-99, which decays to technetium-99, a medical isotope (DOE 1996a, Appendix B, Section B.1.5). In this SA, target materials are also referred to as residues or target residues. Target materials are not high-level radioactive waste.

environmental impacts associated with the use of conventional processing, like those associated with the melt and dilute technology, were analyzed in the SRS SNF EIS.

Separately, DOE proposes to transport target material, which contains HEU of U. S. origin, from Canada as part of DOE's foreign research reactor acceptance program. The material would be transported in liquid form to SRS. It would be processed in H-Canyon by conventional processing, and the HEU would be recovered for down-blending to LEU. In both the FRR EIS and the SRS SNF EIS, DOE assumed that this material would be transported in a solid form

DOE's purpose and need for action remains, as described in the SRS SNF EIS, to develop and implement a safe and efficient SNF management strategy that includes preparing aluminum-clad SNF and target material stored at SRS or expected to be shipped to SRS for ultimate disposition offsite.[3] Although the SRS SNF EIS also discussed DOE's purpose and need in terms of then-current plans for the availability of a geologic repository, those plans have since changed, as described in this Supplement Analysis (SA).

The Council on Environmental Quality (CEQ) regulations for implementing NEPA, 40 CFR 1502.9(c)(1), direct Federal agencies to prepare a supplement to an EIS when "(i) [t]he agency makes substantial changes in the proposed action that are relevant to environmental concerns, or (ii) [t]here are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts." DOE regulations for compliance with NEPA, 10 CFR 1021.314(c), direct that when it is unclear whether a supplement to an EIS is required, DOE must prepare an SA to assist in making that determination. This SA summarizes relevant NEPA reviews, and evaluates the potential environmental impacts of managing certain aluminum-clad SNF and target material using conventional processing in H-Canyon rather than the melt and dilute process. DOE proposes to change the management method for certain SNF and target material from melt and dilute to conventional processing. DOE also proposes to transport and receive target material from Canada in liquid rather than solid form. This SA will assist DOE in determining whether a Supplemental EIS or a new EIS is required.

2. PRIOR NEPA REVIEWS

A. SNF PEIS

Volume 1 of the SNF PEIS evaluated the range of programmatic alternatives for safely, efficiently, and responsibly managing existing and projected quantities of SNF until the year 2035. The programmatic alternatives are as follows: Decentralization, where most SNF would be stored and stabilized near the generation site; Regionalization, where existing and projected SNF would be distributed among alternative DOE sites based on fuel type or geographic location (e.g., an eastern site and a western site); and Centralization, where existing and projected SNF would be consolidated at one DOE site. DOE evaluated the Hanford Reservation (Hanford), SRS, Idaho National Laboratory (INL), Oak Ridge Reservation (Oak Ridge), and the Nevada

[3] Implementing the actions described in this SA would allow HEU to be dispositioned offsite by transferring it as LEU to fuel vendors. Fission products would be transferred to the SRS liquid radioactive waste tanks for vitrification in the Defense Waste Processing Facility (DWPF). DWPF canisters would be safely stored at SRS pending disposal in a geologic repository.

National Security Site (NNSS, formerly known as the Nevada Test Site) as possible SNF management sites, consistent with their capabilities for SNF management.

Following completion of the SNF PEIS, DOE decided to regionalize SNF management by fuel type (Alternative 4a) at three DOE sites: Hanford production reactor fuel (which, based on current estimates, constitutes 88 percent by mass of the existing and projected inventory) would remain at the Hanford site, aluminum-clad fuel would be consolidated at SRS, and non-aluminum-clad fuel would be consolidated at INL. Among the reasons stated in the Programmatic SNF ROD (DOE, 1995b) for DOE's decision to regionalize SNF management was that the decision would further the consolidation of fuel at DOE sites where the best capability exists to manage that type of fuel, thus enhancing the flexibility to address future requirements for ultimate disposition of the fuel, as they evolve.

B. FRR EIS

The FRR EIS (DOE, 1996a) is tiered from the SNF PEIS, and in it DOE evaluated alternatives for return to the United States of SNF containing HEU enriched in the United States and supplied to foreign countries. Return of HEU for safe storage and disposition advances the United States' nuclear material nonproliferation goals. Appendix B1.5 of the FRR EIS discusses two methods for preparing the target residue materials for transport: calcining and oxidizing. In the FRR EIS, DOE assumed that target material would be transported in solid form, and evaluated the impacts of transportation accordingly. In Appendix B.2.1.2 DOE states that foreign research reactor shipments would be carried out in accordance with regulations set by the Department of Transportation and the Nuclear Regulatory Commission. In the FRR ROD (DOE, 1996b), DOE decided, consistent with the programmatic decision to consolidate storage by fuel type, to transport to, and store aluminum-clad SNF and target material at, the SRS.

C. SRS SNF EIS

DOE evaluated the impacts of alternatives for management of SNF and target material stored at SRS or that would be transported to SRS in the future (e.g., foreign research reactor fuel and target material) in the SRS SNF EIS. In order to facilitate identification of appropriate treatment technologies, DOE grouped the SNF based on characteristics such as fuel size, physical and chemical properties, and radionuclide inventory. The fuel groups are described in the SRS SNF EIS on page 1-7. DOE identified seven technologies that could be used to prepare the SNF for disposition and described the technologies on page 2-8 of the SRS SNF EIS. The applicability of the conventional processing[4] technology to the fuel groups is described on page 2-17 of the SRS SNF EIS. Taking into consideration the technologies applicable to the fuel groups, DOE developed five alternatives that could be used to manage SNF: No Action, Minimum Impact, Direct Disposal, Maximum Impact, and the Preferred Alternative. The action alternatives represent combinations of technologies applied to fuel groups. The alternatives are described in Table 2-8 (page 2-36) and on page 2-35 of the SRS SNF EIS. In the ROD for the SRS SNF EIS, DOE selected the Preferred Alternative (DOE, 2000b).

[4] Conventional processing is a chemical separations process that involves dissolving spent fuel in nitric acid and separating fission products from uranium using solvent extraction.

As part of the Preferred Alternative, DOE stated it would use the melt and dilute technology to treat all Group B[5] fuel (up to about 20 MTHM of aluminum-clad Material Test Reactor fuel from foreign and domestic reactors), all Group C fuel (about 8 MTHM oxide and silicide foreign and domestic reactor fuel and target material) except failed fuel (which DOE would treat by conventional processing) and most Group D fuel (about 0.6 MTHM of foreign research reactor targets).

These fuels total about 28.6 MTHM, based on quantities already stored at SRS and then-estimated quantities located at domestic and foreign reactor locations scheduled or eligible to ship fuel to SRS when the SRS SNF EIS was prepared. Also as part of the Preferred Alternative, conventional processing would be used to manage Group A fuel, consisting of about 19 MTHM of various materials. HEU separated during conventional processing would be down-blended to create LEU feedstock for use in the manufacture of fuel for commercial nuclear reactors. DOE evaluated storing and processing[6] Group E fuel, consisting of less than 0.1 MTHM of special isotope targets. The SRS SNF EIS provided an assessment of the environmental impacts of conventional processing of all of these fuels (except Group F fuel). In addition, DOE provided an analysis of the impacts of transporting the material to SRS by reference to analysis found in the SNF PEIS and the FRR EIS.

DOE issued the Final SRS SNF EIS in March 2000 and issued a ROD on August 7, 2000 (DOE, 2000b). DOE decided to adopt the Preferred Alternative as described above. Although DOE did not advance the melt and dilute technology, DOE has been taking other actions described in the SRS SNF EIS, including using H-Canyon to process Group A fuel, down-blending recovered HEU to LEU, and transporting foreign and domestic research reactor fuel to SRS, since the ROD was issued.

In this SA, DOE is updating its assessment of the environmental impacts of conventional processing for the aluminum-clad SNF (as evaluated in the Maximum Impact Alternative in the SRS SNF EIS) that DOE previously decided to treat through the melt and dilute technology, and up to one MTHM non-U.S.-origin SNF (referred to as "Gap" SNF), if such SNF is received under the Global Threat Reduction Initiative (DOE, 2009)[7].

[5] The quantity of Group B fuel analyzed in the SRS SNF EIS was based in part on the projected receipt of about 19.2 metric tons of foreign research reactor spent fuel. Actual receipts are expected to be substantially less than that amount (DOE, 2009).

[6] DOE relied on analysis found in the Interim Management of Nuclear Materials EIS (DOE, 1995c) for the impacts of processing Group E fuel.

[7] Gap Material SNF consists of SNF containing non-U.S.-origin HEU and SNF containing U.S. origin HEU that was not addressed in the FRR EIS. If no other reasonable pathways are identified to address U.S. national security interests, DOE would transfer up to 1 MTHM to the U.S. See the Supplement Analysis for the Disposition of Gap Material – Spent Nuclear Fuel (DOE, 2009) for more information.

3. PROPOSED CHANGES

DOE proposes to use conventional processing for up to approximately 3.3 MTHM of SNF and target material, which is the minimum quantity of SNF necessary to avoid the need for costly modifications to the L-Basin that would allow DOE to accommodate expected receipts of SNF for the foreseeable future. To do this, DOE has estimated that processing approximately 1000 bundles of SNF and up to 200 HFIR cores currently stored at SRS would provide the minimum necessary amount of storage space. DOE also plans to receive FRR target residue material from Canada in accordance with U.S. acceptance policy and consistent with U.S. nonproliferation objectives. The target material, containing U.S.-origin HEU in liquid form would be shipped in Type B casks certified by the U.S. Nuclear Regulatory Agency. The 3.3 MTHM proposed for processing is almost 85 percent less than the 28.6 MTHM evaluated in the SRS SNF EIS. The separated uranium from any future conventional processing would be down-blended to LEU for use as feedstock for commercial nuclear fuel fabrication.

Conventional processing and down-blending would take place in the H-Area complex, including H-Canyon, at SRS. As discussed in Section 4.A. of this SA, DOE would install and operate a third dissolver in H-Canyon to return the dissolving capacity for SNF to the level supported by H-Canyon's off-gas system and processing capability[8], which are the capacities evaluated in the SRS SNF EIS. Waste streams would be sent to the Saltstone Processing Facility for processing and disposal in the Saltstone Disposal Facility, and the Defense Waste Processing Facility (DWPF) and Effluent Treatment Facility for disposition, as described in the SRS SNF EIS. Plutonium present in the SNF would not be separated from the fission products, but would be transferred as high-level liquid waste for vitrification in DWPF at SRS. SRS will continue to receive and store foreign and domestic research reactor SNF and target material and, as needed, prepare fuel for transfer to H-Area for processing. DOE would make minor modifications to H-Canyon to allow receipt of the Canadian target material in liquid form (instead of solid as originally envisioned). The H-Canyon truck well would be modified to accommodate liquid unloading and venting and flushing of the shipping container. A temporary transfer system would be installed to accommodate the volume and transfer rate, and to allow a volume of the liquid to be accumulated and fed into the processing system without disrupting the routine receipt and processing of liquid laboratory sample returns.

DOE has consolidated spent fuel storage in the L-Area Basin and maintained water quality to prevent degradation of the fuel cladding, and no incidents of cladding deterioration have occurred.[9] The 3.5 million gallons of water in the basin (approximately 10 feet above the top of the fuel) protects personnel from exposure to radiation. If DOE identifies any imminent health and safety concerns involving any aluminum-clad SNF in storage, DOE would use conventional processing to stabilize the material of concern, as explained in the ROD for the SRS SNF EIS[10] (DOE, 2000b).

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[8] One H-Canyon dissolver currently supports dissolution of plutonium metal, preparatory to oxidizing it in HB-Line to prepare plutonium oxide feed material for the Mixed Oxide Fuel Fabrication Facility (DOE, 2012).

[9] The Defense Nuclear Facilities Safety Board issued a technical report in January 2013 regarding storage of reactive metal fuel in L-Basin (DNFSB, 2013). That report does not address the aluminum-clad SNF or target materials that are the subject of this SA.

[10] SRS is currently processing a small amount of aluminum-clad SNF because of potential health and safety vulnerabilities.

During the period of SNF storage in L-Area and processing in H-Canyon, maintenance activities would be performed to ensure the continued safe and efficient operation of those facilities. The routine maintenance would be similar to what has been performed for the past 60 years such as replacing jumpers, vessels, wiring, and controllers, and maintaining water quality in the L-Area fuel storage facility. DOE does not anticipate any major facility modifications to H-Canyon, the L-Area fuel storage facility, or associated facilities.

4. COMPARISON OF PROPOSED CHANGES TO PRIOR NEPA REVIEWS

As stated previously, DOE would operate the existing H-Canyon, the L-Area fuel storage facility, and associated facilities to manage aluminum-clad SNF, including SNF currently at SRS, and SNF and target material expected to be shipped to SRS. DOE evaluated the potential environmental impacts of the activities to manage SNF and target material at SRS in Chapter 4 of the SRS SNF EIS. In reviewing these analyses to prepare this SA, DOE determined that the analyses of the impacts of storage and processing of SNF presented in the SRS SNF EIS continue to accurately represent the potential impacts of the SNF management actions that are the subject of this SA. Future operations would not be significantly different than past SNF management activities at SRS, including SNF processing in H-Canyon, upon which impact estimates in the SRS SNF EIS were based.

Since completion of the SRS SNF EIS, DOE has used H-Canyon to process primarily unirradiated fuel and HEU materials. During these operations, DOE has not identified any instances where the impacts of operations were significantly different than expected or analyzed in the SRS SNF EIS or prior NEPA documents (DOE, 1995c; DOE, 1996c). This experience indicates the continued relevance of existing NEPA analysis generally.

The following sections discuss key aspects of managing SNF and liquid target materials at SRS using conventional processing to determine whether they would be significantly different than environmental impacts described in the SRS SNF EIS.A discussion of intentional destructive acts is also included. In other areas (e.g., cultural resources, land use, generation of solid low-level radioactive waste), DOE has not observed and does not anticipate impacts greater than those described in the SRS SNF EIS.

A. SNF Processing

DOE proposes to use conventional processing for up to 3.3 MTHM of aluminum-clad SNF and target residue materials at the SRS. The SRS SNF EIS evaluated the use of two dissolvers in H-Canyon. However, in 2012, DOE allocated one dissolver to processing plutonium. (See Section 5, "Relationship to Surplus Plutonium Disposition Supplemental EIS" below.) DOE proposes to install and operate a third H-Canyon dissolver to return the dissolving capacity for SNF to the capacity evaluated in the SRS SNF EIS. The dissolvers operate independently of one another. The only common feature is the crane used to charge the dissolvers. The current safety basis documentation for H-Canyon supports ongoing operations with one dissolver dedicated to plutonium and one dedicated to SNF (Savannah River Nuclear Solutions, LLC, 2012). DOE will update the safety basis documentation if a decision is made to install a third dissolver.

Installation of a third dissolver would be carried out and contained in the H-Canyon and result in the generation of some construction waste, which would be managed using existing SRS procedures and facilities. DOE would continue to use one dissolver to process plutonium material; plutonium dissolution does not require use of the off-gas treatment system or H-Canyon's solvent extraction capacity and raffinate systems. The operation of two dissolvers and the associated off-gas and raffinate systems for processing SNF and target material would not result in air and liquid releases, or radiological impacts to workers and the public, that are significantly different from results reported in the SRS SNF EIS. The process has not changed, and to ensure safe operations, activities are continually monitored to ensure the facility's safety basis is maintained. In addition, DOE continues to evaluate physical modifications to the H-Canyon facility and process chemistry changes that would reduce personnel exposure and waste generation. In the past several years, DOE has reduced waste generation at H-Canyon by two to five percent.

B. HEU Processing and Down-Blend

In the Disposition of Surplus Highly Enriched Uranium EIS (DOE, 1996c), DOE evaluated the processing and down-blending of up to 85 percent of U.S. surplus HEU (up to about 170 MT) to a U-235 enrichment level of about four percent for eventual sale and commercial use as reactor fuel. DOE decided (DOE, 1996d) to use any of three technologies (liquid blending, gas blending, or molten metal blending) at any of four sites (Oak Ridge, SRS, the Babcock and Wilcox Naval Nuclear Fuel Facility in Lynchburg, Virginia, and the Nuclear Fuel Services, Inc. Plant in Erwin, Tennessee) to accomplish the down-blending. Since DOE made that decision, HEU has been down-blended at SRS using the liquid uranyl nitrate process. The down-blended product is then transported to Erwin, Tennessee, and used as feedstock to fabricate fuel for reactors operated by the Tennessee Valley Authority.

In 2007, DOE prepared an SA (DOE, 2007) to determine if certain changes in the HEU disposition program required additional NEPA review. DOE proposed new end users for existing program material, proposed new disposition pathways for certain HEU, and proposed down-blending of additional HEU. The new end users and disposition pathways do not affect SRS operations. In the 2007 SA, DOE also reviewed the down-blending activities and quantities that had been evaluated in the HEU EIS. The 2007 SA found that the additional activities and amount of HEU DOE proposed to down-blend at SRS would not substantially change the impacts analyzed in the HEU EIS or present significant new information relevant to environmental concerns, and that no further NEPA review was required. The quantities of HEU considered within this SA are subsumed within the HEU EIS and 2007 SA, and the proposal evaluated in this SRS SNF SA presents no new information relevant to environmental concerns.

C. Transportation and Receipt of HEU Target Material

Processing irradiated HEU targets to recover the produced radioisotopes leaves residues that contain HEU. Depending on the process used to recover the isotopes, the residues may be in liquid or solid form. In the present proposal, DOE would receive target material in liquid form from Canada at an existing storage tank in H-Canyon at SRS. DOE would accumulate enough target material for efficient processing, and anticipates several campaigns would be required to process the entire quantity. The shipping schedule would be coordinated with the processing schedule to minimize the accumulation of target material at SRS and ensure adequate tank capacity is available prior to each processing campaign. Molybdenum-99 has been recovered from the targets, and DOE's action described herein would be recovery of HEU from the target residues. Consistent with DOE's 2004 Revised ROD for the FRR EIS, DOE would not accept the target material if the H-Canyon were unavailable (DOE, 2004). If H-Canyon were to be not operational for an extended period, the processing of liquid target material already at SRS (or any other material already in process) would continue through the normal processing steps, including blending down to LEU and shipment off-site. H-Canyon would be placed in a safe condition under surveillance and maintenance consistent with safety basis requirements. DOE expects that target material from other nations[11] would be shipped in solid form, as evaluated in the FRR EIS (DOE, 1996a).

HEU target residue material from Canada would be shipped and received as a liquid. The target material is currently stored at the Chalk River facility in Ontario, Canada. HEU solutions would be placed in small tanks which would be placed in a Nuclear Regulatory Commission (NRC)-certified Type B cask. Use of the small tanks helps ensure safety, including eliminating the potential for criticality. Each cask would be placed in an International Standards Organization container and transported one per truck. DOE has conservatively estimated the number of shipments for purposes of analysis, to account for uncertainty regarding factors such as the actual loading of each tank and dilution rates (See Appendix A). This would be the first shipment of target material under DOE/National Nuclear Security Administration's (NNSA) Global Threat Reduction Initiative for the purpose of eliminating material in civilian commerce that can be used in an improvised nuclear device as evaluated in the FRR EIS.

The security, safety, and technical issues or concerns associated with transporting target material (liquid HEU) are similar to those for other forms of nuclear material. The material would be transported in transport packages licensed by the U.S. NRC. This is contingent upon successful completion of the ongoing effort to certify the NAC-LWT cask to be used to transport the liquid target materials.

All shipments would be conducted in a manner that meets the regulatory requirements of the Department of Transportation (DOT), NRC, and the Department of Homeland Security. (See Appendix A, section 3, for a discussion of packaging and transportation regulations.) This includes use of routes in the U.S. selected in accordance with DOT regulations; DOE approval of the Transportation and Security Plans; an export license from the originating country (Canada); and DOE approval to ship, signifying that all advanced preparations are complete to receive the authorized material into the specified DOE receiving facility. No target material or waste from processing target material would be returned to Canada.

DOE has evaluated the impacts of transporting this material to SRS in liquid form, and finds that no worker or public latent cancer fatalities (LCF) would occur due to incident free transportation, and that the per-shipment incident-free impacts are very small and on the same order of

[11] In addition to the target materials from Canada, the FRR EIS identifies target materials from three countries (Argentina, Belgium, and Indonesia) in Group D.

magnitude as those estimated for the shipment types analyzed in the FRR EIS (DOE 1996a). The transportation evaluation contained in Appendix A indicated that non-radiological accident risks, the potential for fatalities as a direct result of traffic accidents, present the greatest risks related to transportation of liquid HEU, but no traffic fatalities would be expected. The evaluation assumed a representative transportation route for the purposes of analysis; actual routes would be determined by the shipper in accordance with all applicable transportation regulations to ensure the safety of transportation workers and the general public. Radiation doses from the most severe accident, a long duration high-temperature fire, would not cause an LCF. The overall impacts of transporting liquid HEU are very small and are less than those described in the FRR EIS (DOE, 1996a). See Appendix A of this SA for more details on the potential impacts of transporting the target material in liquid form.

Minor modifications would be required to receive liquid material at H-Canyon. The transfer mechanism to an H-Canyon tank would be modified to allow connection to the shipping cask for transfer of the liquid from the cask to the tank. Spill control measures would be instituted and could include dripless transfer connections and nozzles. These modifications would all take place within the footprint of H-Canyon and result in generation of a small amount of construction waste that would be disposed of in existing SRS facilities. Prior to commencing shipments of liquid HEU, DOE will evaluate the H-Canyon safety basis to determine if the impact of the loss of the volume of material in a shipping cask is already addressed or if an unreviewed safety question determination is required.

D. Waste and Tank Space

SNF processing generates liquid waste requiring management and disposition. The quantities of liquid waste that would be generated under this proposal have been included in the SRS Liquid Waste System Plan (Savannah River Remediation, 2012). SNF processing under this proposal would not significantly affect the quantity or type of waste that would be disposed of in the Saltstone Disposal Facility. DOE would employ several methods to ensure safe management of the liquid waste. As described in the Salt Processing Alternatives Supplemental EIS (DOE, 2001) and the Supplement Analysis for Salt Processing Alternatives (DOE, 2006), DOE is in the process of constructing the Salt Waste Processing Facility (SWPF), a key part of a system designed to manage the salt fraction of the radioactive liquid waste currently stored at SRS. In addition to constructing this facility, DOE is currently operating the Modular Caustic Side Solvent Extraction Unit (MCU) and the Actinide Removal Process (ARP) to process salt waste and maintain adequate tank waste space until SWPF commences operations. The treated, solidified low-level waste from SWPF and MCU/ARP is being and will continue to be disposed of in the Saltstone Disposal Facility at SRS, and the high-activity waste fraction will continue to be transferred to DWPF for treatment as high-level waste.

DOE estimates that up to approximately 24 DWPF canisters of vitrified waste would be generated as a result of the conventional processing of up to approximately 3.3 MTHM of SNF. In the context of the approximately 7,000 DWPF canisters that DOE estimates will be produced, and the up to 10,000 canisters DOE evaluated in the Defense Waste Processing Facility EIS (DOE, 1982) this increase is not significant and is within current production and planned storage capabilities at SRS.

DOE had previously planned to dispose of DWPF vitrified waste canisters in the Yucca Mountain geologic repository for SNF and high-level waste (HLW). Although the Secretary has determined that Yucca Mountain is not a workable option for a geologic repository, the Department remains committed to meeting its obligations to safely dispose of used (i.e., spent) nuclear fuel and HLW. The Secretary's *Strategy for the Management and Disposal of Used Nuclear Fuel and High-level Radioactive Waste*, January 2013, endorses the key principles of the 2012 Blue Ribbon Commission on America's Nuclear Future report and represents an initial basis for discussions among the Administration, the Congress, and other stakeholders toward a sustainable path forward for disposition of nuclear waste.

E. Consideration of Intentional Destructive Acts

DOE has always provided, and continues to provide, substantial safeguards and security measures for both transportation and storage of nuclear materials, including HEU and SNF. Safeguards and security are designed to prevent theft or diversion of materials, and to prevent exposure of workers and the public to radiation from the material during transportation and storage. DOE recognizes that an attack against an SNF cargo or storage or processing facility does not have to result in diversion of the material to cause very undesirable consequences, such as release of radionuclides into the environment.

Following the events of September 11, 2001, DOE is continuing to consider and implement measures to minimize the risk and consequences of potential terrorist attacks on DOE facilities. DOE conducts vulnerability assessments and risk analyses in accordance with DOE Order 470.3A, Design Basis Threat Policy, and DOE Order 470.4, Safeguards and Security Program. The safeguards applied to protecting H-Canyon and L-Area at SRS involve a dynamic set of controls and actions to meet threats, and DOE expects that those safeguards will continue to be strengthened and evolve over time. DOE continues to evaluate security scenarios involving malevolent or terrorist acts in an effort to assess potential vulnerabilities and identify improvements to security procedures and response measures. The physical security protection strategy is based on a graded and layered approach supported by a guard force trained to detect, deter, and neutralize adversary activities. Facilities are protected by staffed and automated access control systems, barriers, surveillance systems, and intrusion detection systems.

It is not possible to predict whether or where intentional acts of destruction would occur, or the nature or types of attacks. However, it is reasonable to evaluate severe accidents as comparable to the potential impacts of intentional acts. For the proposal that is the subject of this SA, SNF would be received and stored in the L-Area storage facility. In the SRS SNF EIS, DOE evaluated accident scenarios involving SNF storage in the Receiving Basin for Offsite Fuels and in the L-Area wet storage basin. DOE evaluated accident scenarios in H-Canyon during processing of SNF. In the case of fuel stored in a wet basin, the most severe accident in terms of LCFs resulting from radiation release is a criticality induced by high winds[12]. DOE estimated

[12] In the SRS SNF EIS, DOE estimated that a high-wind induced criticality in the Receiving Basin for Offsite Fuel (RBOF) would result in 6.2 LCFs in the offsite population. RBOF has since been deinventoried. The highest consequences accident in the L-Basin is a water basin drainout, resulting in a non-involved worker dose of 0.0014 rem (compared to a non-involved worker dose of 13 rem for the high-wind induced criticality in RBOF), and an

that such an accident could result in about 6.2 LCF in the offsite population. During H-Canyon processing, the most serious accident is a coil and tube failure with radioactive material released through the facility's cooling tower. DOE estimated that such an accident could result in 39 LCF in the offsite population. Each of these accidents, and others described in the SRS SNF EIS, could also result in non-radiological fatalities, depending on the initiator of the radiological release and structural damage to the facility.

In reviewing the nature and consequences of the accident scenarios described in the SRS SNF EIS, DOE has determined that the consequences of a terrorist attack on the SNF storage and processing facilities are not likely to be greater than the consequences of the severe accidents DOE evaluated. Each facility is very robust, and each is protected as described in the paragraphs above. The potential impacts of intentional destructive acts against these SRS facilities would be similar to the accident impacts presented in the SRS SNF EIS. Although DOE did not analyze intentional destructive acts in the FRR EIS, DOE reviewed existing analyses of acts of sabotage and terrorism on transportation of SNF and high-level radioactive waste. (See Appendix A.) Because the quantities of radioactive material in the target materials are much less than in SNF or high-level radioactive waste, DOE concluded that the estimated impacts of an intentional destructive act on the proposed shipments of target materials would not exceed the potential impacts associated with the results reviewed for SNF and high-level waste.

5. RELATIONSHIP TO SURPLUS PLUTONIUM DISPOSITION SUPPLEMENTAL EIS

DOE is preparing a supplement to the Surplus Plutonium Disposition (SPD) Environmental Impact Statement (EIS) (DOE/EIS-0283, November 1999) to, among other things, evaluate alternatives for disposition of surplus weapons-usable plutonium. Three of those alternatives involve the use of certain H-Canyon facilities (principally a dissolver and HB-Line) to process plutonium for disposition to DWPF for vitrification, prepare plutonium to be manufactured into mixed oxide fuel in the Mixed Oxide Fuel Fabrication Facility (MFFF) (under construction at SRS), or prepare plutonium for disposal at the Waste Isolation Pilot Plant in New Mexico. DOE issued the Draft SPD Supplemental EIS (DOE/EIS-0283-S2) in July 2012. DOE anticipates issuing the Final SPD Supplemental EIS in 2013.

In June 2012, DOE determined that, before completion of the SPD Supplemental EIS, it could begin processing 2.4 MT of non-pit plutonium through the H-Canyon facilities to make it suitable for feedstock for the MFFF (DOE, 2012). This activity began in October 2012. After completing the SPD Supplemental EIS, DOE could decide to process additional plutonium in H-Canyon.

The use of HB-Line for plutonium disposition into DWPF, oxide production for MFFF, or disposal at WIPP would not limit H-Canyon capacity to process SNF and recover the uranium. However, utilizing one H-Canyon dissolver to dissolve plutonium would limit SNF processing to the one remaining dissolver and possibly extend the time to process the SNF. Thus, as described

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MEI dose of 0.016 rem, (compared to an MEI dose of 0.22 rem for the high-wind induced criticality in RBOF). Impacts of the L-Basin accident thus estimated to be much less than those of the RBOF accident. See SRS SNF EIS, Table 4.2-1, p. 4-49.

earlier in this SA, DOE proposes to install a third dissolver to return the dissolving capacity for SNF to the level supported by H-Canyon's off-gas system and processing capability, which are the capacities evaluated in the SRS SNF EIS.

6. CONCLUSION

DOE has reviewed its previous EISs that address SRS facilities and programs involved in existing and proposed SNF and target material management: the SRS SNF EIS, the FRR EIS, the Disposition of Surplus Highly Enriched Uranium EIS, the SRS Salt Processing Alternatives Supplemental EIS, and the relationship of the present proposal to the Surplus Plutonium Disposition Supplemental EIS. This SA addresses the impacts of proposed SNF and target material management actions including transportation, conventional processing, waste management, and down-blending HEU to LEU. The proposal involves the use of existing facilities and existing processes. The changes would use conventional processing in lieu of melt and dilute technology, both of which were analyzed in the SRS SNF EIS, and the installation of a third dissolver in H-Canyon to provide the HEU processing capacity analyzed in the SRS SNF EIS. Separately, the proposal involves the transport, receipt and processing of HEU target materials from Canada in liquid form rather than solid form as analyzed in the FRR EIS. All HEU recovered during operations would be downblended to LEU as evaluated in the Disposition of Highly Enriched Uranium EIS. DOE has also prepared a discussion regarding intentional destructive acts.

The potential health and environmental impacts of processing almost 85 percent less SNF than DOE evaluated originally would not exceed those described in the SRS SNF EIS. While the quantity of fuel is less than anticipated, the characteristics of the fuel have not changed, and radioactive decay has occurred which tends to reduce some radiological impacts.

DOE finds that, due to the transportation and safety measures to be used, the potential impacts of transporting target materials from Canada in liquid form, including potential impacts from terrorism or other harmful acts, would not be significantly different from those analyzed in the FRR EIS. DOE also finds that once the target materials are received on site, the potential risks associated with on-site storage and conventional processing in H-Canyon would not significantly differ from those reported in the SRS SNF EIS. For the down-blending aspect of the proposal, there is no significant change from prior NEPA reviews.

7. DETERMINATION

This SA demonstrates that the potential environmental impacts of processing up to approximately 3.3 MT of SNF and target material by conventional processing in H-Canyon at SRS and down-blending HEU to LEU for use in commercial nuclear reactors, represents neither substantial changes to the proposed action relevant to environmental concerns nor significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts. This SA also finds that potential environmental impacts associated with transportation of liquid HEU solutions to the SRS from Canada would not significantly differ from the impacts reported in the FRR EIS and would be expected to result in no radiological or non-radiological fatalities. Therefore, pursuant to 10 CFR 1021.314(c), I have determined that a supplemental or new EIS is not required.

Issued at Washington, DC on March 29, 2013

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APPENDIX A

LETTER REPORT:

EVALUATION OF HUMAN HEALTH EFFECTS FROM TRANSPORTATION OF FISSILE SOLUTION STORAGE TANK HIGHLY ENRICHED URANIUM SOLUTION

DOE/EIS-0279-SA-01 and DOE/EIS-0218-SA-06

Letter Report: Evaluation of Human Health Effects from Transportation of Fissile Solution Storage Tank Highly Enriched Uranium Solution

March 2013

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Note: This page of the Table of Contents was corrected on April 1, 2013.

LETTER REPORT
EVALUATION OF HUMAN HEALTH EFFECTS FROM TRANSPORTATION OF FISSILE SOLUTION STORAGE TANK HIGHLY ENRICHED URANIUM SOLUTION

1 Introduction

On May 13, 1996, the United States Department of Energy (DOE) announced the Record of Decision (ROD) (61 FR 25092) for the *Final Environmental Impact Statement on a Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (*FRR SNF EIS*) (DOE 1996). In terms of this policy, and subject to certain conditions, DOE announced its decision to accept and manage foreign research reactor spent nuclear fuel that was originally enriched in the United States (U.S.), as well as certain target material. The FRR SNF Acceptance Program, currently managed by the National Nuclear Security Administration (NNSA), has been in operation since 1996 to implement the decision announced by DOE.

Since May 1996, DOE/NNSA has prepared 4 supplement analyses (SAs) of the original *FRR SNF EIS*, and has published announcements and revisions to the ROD in the Federal Register, as appropriate. Based on the first SA (DOE/EIS-0218-SA1), DOE determined that no further National Environmental Policy Act (NEPA) review was required for using a different route from Concord, California to the Idaho National Laboratory than the reference route evaluated in the *FRR SNF EIS*. Based on the second SA (DOE/EIS-0218-SA-2), DOE revised the ROD to allow more casks (16) to be transported on a ship than originally evaluated and to modify the research reactors and quantities of fuel that could be accepted from countries that were originally evaluated in the *FRR SNF EIS* (65 FR 44767). As a result of the third SA (DOE/EIS-0218-SA-3), the FRR SNF Acceptance Program extended the time period to 20 years, from May 13, 1996, through May 12, 2016, during which highly enriched uranium (HEU) fuel could be irradiated and continue to be eligible for acceptance. The extension does not apply to research reactors that continue to operate on HEU fuel in lieu of conversion to acceptable LEU fuel; however, the extension does provide additional time for new participants to take full advantage of the new dispensation. A 23 year period from May 13, 1996 through May 12, 2019, is now allowed for the acceptance of fuel irradiated during the 20-year window (69 FR 69901). A fourth SA (DOE/EIS-0218-SA-4) supported a DOE decision to expand the program to accept "gap material" SNF that poses a threat to national security, is susceptible for use in an improvised nuclear device, presents a risk of terrorist threat, and has no other pathway to ensure security from theft or diversion (FR). Gap material SNF included a limited quantity of SNF containing non-U.S.-origin HEU and SNF containing U.S.-origin HEU that was not previously addressed in the *FRR SNF EIS*.

Canada is among the countries that are eligible for the spent fuel acceptance program. The *FRR SNF EIS* expected to receive target materials from Canada. Target materials, (in a form of fissile solutions from a very small burnup), are residual materials from HEU target fuels that have been irradiated in a research reactor to produce molybdenum-99, which decays to technetium-99, a medical isotope. Two methods were identified in the *FRR SNF EIS*, namely calcining or oxidizing, to prepare this material for transport to the U.S. There is now a proposal to transport the fissile solution in a transportation cask certified by the NRC.

This assessment reviews the transport of radioactive liquid solutions from the Canadian border to the Savannah River Site in South Carolina. These liquid solutions would originate from Chalk River Laboratories and would consist of HEU solution). The route described in this evaluation is representative only for the purposes of analysis. The actual routes would be determined by the shipper in accordance with all applicable transportation regulations to ensure the safety of the involved transportation workers and the general public.

The topics in this report 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 that could affect the results.

2 Scope of Assessment

The scope of the transportation human health risk assessment addresses the potential radiological and nonradiological impacts, transportation modes, and receptors associated with the transport of HEU in solution at Chalk River Laboratories in Canada. The assessment addresses impacts only on the U.S. portion of the transportation route.

2.1 Transportation-Related Activities

The transportation risk assessment is limited to estimating the human health risks related to transportation. 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 volume or infrastructure are not quantitatively evaluated in this analysis. These impacts would be insignificant since there would be only about one shipment per week and there would not be any road closures or other procedures implemented that would affect traffic flow.

Liquid radioactive solution from Chalk River Laboratories in Canada would be placed into containers that would then be placed into NAC-LWT casks, one container per cask. The NAC-LWT cask vendor (NAC International) possesses a valid competent authority certification for the cask from the U.S. Department of Transportation (DOT); however, a revision to the certification is needed because the container and HEU solutions were not included in the original certification. Each cask would be placed inside a 6.1-meter (20-foot) ISO container and there would be one ISO container per truck.

2.2 Radiological Impacts

Radiological risks (i.e., those risks that result from the radioactive nature of the materials) are assessed for both incident-free (normal) and accident transportation conditions. The radiological risk associated with incident-free transportation conditions would result from the potential exposure of people to external radiation in the vicinity of a shipment. The radiological risk from transportation accidents would come from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people.

All radiological impacts are calculated in terms of radiation dose and associated health effects in the exposed populations. The radiation dose calculated is the total effective dose equivalent (see Title 10 of the Code of Federal Regulations [CFR], Part 20 [10 CFR Part 20]), which is the sum of the effective dose equivalent from external radiation exposure and the 50-year committed effective dose equivalent from internal radiation exposure. Radiation doses are presented in units of roentgen equivalent man (rem) for individuals and person-rem for collective populations. The impacts are further expressed as health risks in terms of latent cancer fatalities (LCFs) in exposed persons using a dose-to-risk conversion factor of 0.0006 LCFs per rem or person-rem of exposure for both the public and workers (DOE 2002c).

2.3 Nonradiological Impacts

In addition to radiological risks posed by transportation activities, vehicle-related risks are also assessed for nonradiological causes (i.e., causes related to the transport vehicles, not the radioactive cargo) for the same transportation routes. The nonradiological transportation risks, which would be incurred for similar shipments of any commodity, are assessed for accident conditions. The nonradiological accident risk refers to the potential occurrence of transportation accidents that result in fatalities unrelated to the 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 5.2, these emission impacts, in terms of excess latent mortalities, were not considered.

2.4 Transportation Modes

All shipments of radioactive materials are assumed to take place by exclusive-use truck.

2.5 Receptors

Transportation-related risks are calculated and presented separately for workers and members of the general public. The workers considered are truck crew members involved in transportation and inspection of the packages. The general public includes all persons who could be exposed to a shipment while it is moving or stopped during transit. For incident-free operation, the affected population includes individuals living within 800 meters (0.5 miles) of each side of the road. Potential risks are estimated for the affected populations and the hypothetical maximally exposed individual (MEI). For incident-free operation, the MEI would be a resident living near the highway who is exposed to all shipments transported on the road. For accident conditions, the affected population includes individuals residing within 80 kilometers (50 miles) of the accident, and the MEI would be an individual located directly downwind from the accident. The risk to the affected population is a measure of the radiological risk posed to society as a whole. As such, the impact on the affected population is used as the primary means of evaluating impacts.

3 Packaging and Transportation Regulations

This assessment was performed consistent with packaging and transportation regulations. These regulations are presented in the *FRR SNF EIS*, Appendix E, Section E.3.1. The latest summary of the regulations are presented in DOT's *Radioactive Material Regulations Review* (DOT 2008). Appendix B, Section B.2.1.3 of the *FRR SNF EIS* summarizes the regulations related to cask design.

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

- Protect persons and property from radiation emitted from packages during transportation by specific limitations on the allowable radiation levels
- Contain radioactive material in the package (achieved by packaging design requirements based on performance-oriented packaging integrity tests and environmental criteria)
- Prevent nuclear criticality (an unplanned nuclear chain reaction that could occur as a result of concentrating too much fissile material in one place)

- Provide physical protection against theft and sabotage during transit

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. These standards include requirements that the package and its contents be subcritical (a nuclear chain reaction cannot be sustained). This analysis therefore does not address criticality concerns.

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

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

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

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

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

4 Transportation Analysis Impact Methodology

The transportation risk assessment performed for this analysis is consistent with the methodology used in the *FRR SNF EIS*, Appendix E, Section E.5. Transportation impacts calculations 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 reasonably foreseeable scenarios that could damage transportation packages, leading to releases of radioactive materials to the environment.

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

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 RADTRAN 6 computer code, an updated version of RADTRAN 4 (used for the analyses in the *FRR SNF EIS*), was used for accident risk assessments to estimate the impacts on populations. A number of changes (not including user-interface upgrades and new features) that affect the calculation of incident- free and accident impacts have occurred since RADTRAN 4 was used. Changes relevant to the current analysis include (Weiner 2012, Dennis et al. 2008):

- Upgrading the library of radionuclides in the computer code from 65 to 148 radionuclides, while the number of radionuclides that can be analyzed at a given time increased from 20 to 40
- Updating the dose conversion factors from Federal Guidance Report (FGR) 11/12 to factors published in International Commission on Radiological Protection (ICRP) Publication 72
- Allowing fixed stop parameters for calculation of maximally exposed individuals to be user-defined instead of fixed
- Allowing user-defined dispersion parameters
- Allowing any number of isopleths to be used up to 30, as opposed to being fixed at 18
- Allowing user-defined release heights as opposed to calculating only for ground-level release
- Updating ingestion dose and food transfer factors and calculations
- Correcting a resuspension dose error, resulting in about 100 times lower accident dose
- Removing the 50-year dose component from ground shine to an individual residing on the site of a radiological transportation accident, lowering the accident risk results.

Consistent with the *FRR SNF EIS*, the RISKIND computer code (Yuan et al. 1995) was used to estimate the doses to MEIs and populations for the worst-case maximum reasonably foreseeable transportation accident. RISKIND Version 2.0 was used for this analysis whereas RISKIND Version 1.11 was used for the *FRR SNF EIS*; however, the primary differences lie in the functionality of the code (such as the addition of a mapping function and user interface improvements) with little influence on the calculation of impacts.

4.1 Transportation Routes

To assess incident-free and transportation accident impacts, consistent with the *FRR SNF EIS*, route characteristics were determined for a highway route beginning at the U.S. border and proceeding to South Carolina area where secondary roads are used to travel to SRS.

Because of the unavailability of both the HIGHWAY code that was used in the *FRR SNF EIS*, and the Web-TRAGIS code that replaces the HIGHWAY code, information from TRAGIS-generated reports for different routes were used to develop distance and population density information representative of the route being analyzed. Population density information, originally determined from 2000 U.S. Census data, was escalated to 2013 using state-level population growth rates between the 2000 census and 2010 census (Census 2010) to be representative of population densities.

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 EIS are summarized in **Table 1**. Rural, suburban, and urban areas are characterized according to the following breakdown (Johnson and Michelhaugh 2003):

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

Table 1 Generic Offsite Transport Truck Route Characteristics Used in Calculations

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*	
Canadian Border	Savannah River Site	1,653	936	647	70	20	428	4,312	953,800

[a] Population density information, originally determined from 2000 U.S. Census data, was escalated to 2013 using state-level population growth rates between the 2000 census and 2010 census (Census 2010).
[b] For offsite shipments, the estimated number of persons residing within 800 meters (0.5 miles) along the transportation route, projected to 2013.
Note: To convert from kilometers to miles, multiply by 0.62137; to convert from number per square kilometer to number per square mile, multiply by 2.59. Rounded to nearest kilometer.

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

4.2 Radioactive Material Shipments

Transportation of the liquid HEU would occur in NAC-LWT casks, a certified packaging, on exclusive-use vehicles. Use of legal-weight heavy combination trucks is assumed for highway transportation. Type B packages are generally shipped on trailers designed specifically for the packaging being used; in this analysis, the NAC-LWT would be placed in a specially-made ISO container for shipment. **Table 2** shows the characteristics of the NAC-LWT cask and the associated ISO container.

Table 2 Cask and Container Characteristics

Container	*Container dimensions (meters)* [b]	*Container Mass (kilograms)* [c]	*Shipment Description*
ISO container	2.4W × 2.4H × 6.1L	2,200 (empty)	1 per truck
NAC-LWT	1.1D × 5.1L	25,400 (filled)	1 per ISO container

H = height; ISO = International ; L = length; W = width.
Note: To convert from meters to feet, multiply by 0.3048. Source: NRC 2012.

4.3 Radionuclide Inventories

Each NAC-LWT cask would contain HEU solution. **Table 3** lists the radionuclide inventory for this solution. This inventory is different in chemical form and quantities from that listed for target material in Table E-5 of the *FRR SNF EIS*.

Table 3 Content of a Fully Loaded NAC-LWT Shipping Cask

Isotopes	Becquerel	Curie
U-234	6.53×10^{9}	1.76×10^{-1}
U-235	1.29×10^{8}	3.47×10^{-3}
U-236	8.42×10^{7}	2.27×10^{-3}
U-237	2.06×10^{12}	5.56×10^{1}
U-238	1.29×10^{6}	3.47×10^{-5}
Np-237	1.04×10^{6}	2.80×10^{-5}
Pu-239	2.99×10^{8}	8.07×10^{-3}
Pu-240	2.07×10^{7}	5.58×10^{-4}
Sr-90	1.01×10^{13}	2.73×10^{2}
Y-90	1.01×10^{13}	2.73×10^{2}
Y-91	2.42×10^{6}	6.52×10^{-5}
Zr-95	1.08×10^{7}	2.92×10^{-4}
Nb-95	2.39×10^{7}	6.46×10^{-4}
Ru-106	2.55×10^{11}	6.89
Rh-106	2.55×10^{11}	6.89
Te-127m	1.97×10^{6}	5.33×10^{-5}
Te-127	1.91×10^{7}	5.15×10^{-4}
I-129	2.94×10^{6}	7.95×10^{-5}
Cs-137	1.46×10^{13}	3.93×10^{2}
Ce-144	1.70×10^{12}	4.60×10^{1}
Pm-147	7.25×10^{12}	1.96×10^{2}

5 Incident-free Transportation Risks

5.1 Radiological Risk

Incident-free impacts are calculated in the same manner as described in the *FRR SNF EIS*, Appendix E, Section E.5.1. Consistent with the *FRR SNF EIS*, Appendix E, Section E.6.2, the transport index for the transport package was assumed to be 10, which is the regulatory limit.

The radiological risks from transporting the radioactive material 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 2002c). This factor is larger than the factors used in the *FRR SNF EIS*, Appendix E, Section E.6.6, where a conversion factor of 0.0005 LCFs per rem was assumed for the public, and 0.0004 LCFs per rem was assumed for workers.

5.2 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. While the risk due to truck emissions was estimated in the *FRR SNF EIS*, it was only estimated for the portion of the route passing through an urban area. This risk was not quantitatively estimated in this analysis, but it is noted that the number of vehicles trips would be comparable to that evaluated in the *FRR SNF EIS* and an exceedingly small fraction of the total annual mileage from all vehicles along this route.

5.3 Maximally Exposed Individual Exposure Scenarios

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

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

- A person caught in traffic and located 1.2 meters (4 feet) from the surface of the shipping container for 30 minutes

- A resident living 30 meters (100 feet) from the highway used to transport the shipping container

- A service station worker at a distance of 16 meters (50 feet) from the shipping container for 50 minutes

The above specifications are slightly different than those used in the *FRR SNF EIS*, but considered to be more representative of the current conditions for radioactive material transports. 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. Commercial drivers are subject to Occupational Safety and Health Administration regulations, which limit the whole body dose to 5 rem per year (29 CFR 1910.1996(b)), and the U.S. Department of Transportation requirement of 2 millirem per hour in the truck cab (49 CFR 173.411). Other workers include inspectors who would inspect the truck and its cargo along the route. One inspector was assumed to be at a distance of 1 meter (3.3 feet) from the cargo for a duration of 1 hour.

6 Transportation Accident Risks

6.1 Methodology

Accident impacts are calculated in the same manner as described in the *FRR SNF EIS*, Appendix E, Section E.5.2, taking into account the information in Sections 6.2 to 6.5.

6.2 Accident Rates

A summary of how accident rates are used can be found in *FRR SNF EIS*, Section, E.6.3. In the *FRR SNF EIS*, calculation of accident risks was based on vehicle accident and fatality rates provided in *Longitudinal Review of State-Level Accident Statistics for Carriers of Interstate Freight* (Saricks and Kvitek 1994). For this analysis, vehicle accident and fatality rates were taken from data provided in the revised version of the same report, *State-Level Accident Rates for Surface Freight Transportation: A Reexamination* (Saricks and Tompkins 1999).

For this analysis, state-level accident rate values from Saricks and Tompkins (1999) were used to determine a route-specific accident rate based on the distance traveled in each population zone in each state.

Review of the truck accidents and fatalities reports by the Federal Carrier Safety Administration indicated that state-level accidents and fatalities were underreported. For the years 1994 through 1996, which formed the bases for the analysis in the Saricks and Tompkins 1999 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. The possibility of underreporting in the Saricks and Kvitek 1994 report was not addressed in the *FRR SNF EIS*.

6.3 Accident Severity Categories and Conditional Probabilities

The same approach to using accident severity categories and conditional probabilities that was applied in the *FRR SNF EIS*, as described in Appendix E, Section E.6.4.1 was used for this assessment. The analysis in the *FRR SNF EIS* used accident severity fractions from *Shipping Container Response to Severe Highway and Railway Accident Conditions* (the Modal Study) (NRC 1987). A later study, *Reexamination of Spent Fuel Shipping Risk Estimates* (the Reexamination Study), (NRC 2000), updated severity categories and conditional probabilities for spent nuclear fuel casks. For this analysis, the accident risk is provided using accident severity categories and conditional probabilities from the Reexamination Study; tables presenting results include a footnote showing what the impacts would be if information from the Modal Study was used. The accident risk using the Reexamination Study as a basis is about 100 times lower than if the Modal Study is used.

6.4 Atmospheric Conditions

The same approach to applying atmospheric conditions as described in the *FRR SNF EIS*, Appendix E, Section E.6.5 was used for this assessment.

6.5 Radioactive Release Characteristics

Radiological consequences were calculated by assigning radionuclide release fractions on the basis of the type and form of radioactive material, the type of shipping container, and the accident severity category. For this analysis, release fractions were selected that represent a liquid being transported in a Type B cask for a severity category VI accident.

6.6 Acts of Sabotage or Terrorism

In the aftermath of the 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 a concerted effort 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 an enveloping analysis for this analysis. 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. These events would lead to an increase in risk of fatal cancer to the MEI by 2 to 7 percent (DOE 2002a). The quantity of HEU in solution transported 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 HEU solution.

7 Risk Analysis Results

Per-shipment risk factors have been calculated for the collective populations of exposed persons and for the crew for the anticipated route and shipment configuration, consistent with the analysis performed for the *FRR SNF EIS*. Radiological risk factors per-shipment for incident-free transportation and accident conditions are presented in **Table 4**. These factors have been adjusted to reflect the projected population in 2013 and two trucks in a shipment. For incident-free transportation, both dose and LCF risk factors are provided for the crew and exposed population.

Table 4 Risk Factors per Shipment of HEU Solution

			Incident-Free				*Accident*	
			Crew		*Population*			
Radioactive Material	*Origin*	*Transport Destination*	*Dose (person-rem)*	*LCFs*	*Dose (person-rem)*	*LCFs*	*Radiological Risk (LCF)* [a]	*Non-radiological Risk (traffic fatalities)*
HEU solutions	Canadian Border	SRS	0.28	2×10^{-4}	0.12	7×10^{-5}	8×10^{-8}	9×10^{-5}

HEU = highly enriched uranium; LCF = latent cancer fatality; SRS = Savannah River Site.

[a] The radiological risk is based on updated accident severity fractions from the Reexamination Study (NRC 2000). If the earlier Modal Study (NRC 1987) severity fractions were used, as in the *FRR SNF EIS*, the radiological risk would be 6×10^{-6}.

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. The nonradiological risk represents traffic fatalities resulting from transportation accidents.

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 risk is 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. Although persons are residing within an 80-kilometer (50-mile) radius along the transportation route, they are generally quite far from the route. Because RADTRAN 6 uses an assumption of homogeneous population, it would greatly overestimate the actual doses because this assumption theoretically places people directly adjacent to the route where the highest doses would be present.

As indicated in Table 4, all per-shipment risk factors are less than one. This means that no LCFs or traffic fatalities are expected to occur during each transport. For example, the risk factors to truck crew and population for transporting one shipment of HEU solutions to SRS are given as 2×10^{-4} and 7×10^{-5}LCFs, respectively. This risk can also be interpreted as meaning that there is a chance of 1 in 5,000 that an additional latent fatal cancer could be experienced among the exposed workers from exposure to radiation during one shipment of this material. Similarly, there is a chance of 1 in 14,000 that an additional latent fatal cancer could be experienced among the exposed population residing along the transport route due to one shipment. It should be noted that the maximum allowable dose rate in the truck cab is 2 millirem per hour.

Based on a conservatively estimated number of shipments, the risk to the crew of all shipments is 1 x 10-2 LCFs and 6 x 10-3 for the population. Radiological accident risk would be 6 x 10-6 LCFs.

Nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks, with a fatality risk of 0.007 fatalities. Considering the average number of traffic fatalities in the United States is about 33,000 per year (DOT 2011), the traffic fatality risk for transport of the HEU solutions would be very small.

The risks to various exposed individuals under incident-free transportation conditions have been estimated for the hypothetical exposure scenarios identified in Section 5.3. The maximum estimated doses to workers and the public MEIs are presented in **Table 5**. Doses are presented on a per-event basis (person-rem per event, per exposure, or per shipment), because it is generally unlikely that the same person would be exposed to all events. For those individuals that could have multiple exposures, the cumulative dose could be calculated. Worker (i.e. driver) exposures cannot exceed the regulatory limit of 5 rem per year. 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 HEU solution for 30 minutes is calculated to be 0.015 rem (15 millirem). This is generally considered a one-time event for that individual, although this individual may encounter another exposure of a similar or longer duration in his/her lifetime. An inspector inspecting the conveyance and its cargo would be exposed to a maximum dose rate of 0.07 rem (or 70 millirem) per hour if the inspector stood within 1 meter of the cargo for the duration of the inspection (accounting for a shipment consisting of two trucks, where it is possible the inspector could be exposed to external radiation from both trucks simultaneously).

A member of the public residing along the route would likely receive multiple exposures from passing

hour), and stable conditions were assumed to be Pasquill Stability Class F with a wind speed of 1 meter per second (2.2 miles per hour).
c Population extends at a uniform density to a radius of 80 kilometers (50 miles).
d The MEI under neutral atmospheric conditions is at 125 meters (410 feet) downwind from the accident and exposed to the entire plume of the radioactive release. The MEI under stable atmospheric conditions is at 100 meters (330 feet) downwind from the accident and exposed to the entire plume of the radioactive release.

8 Conclusions

The analysis supports the following conclusions:

- No worker or public LCFs would occur due to incident-free transportation of HEU solutions to SRS. The per-shipment incident-free impacts are on the same order of magnitude as those estimated for the spent nuclear types analyzed in the FRR SNF EIS (see Appendix E, Table E-8 of the FRR SNF EIS).

- The accident risk of transporting HEU solution to SRS would be much less than one LCF. The per-shipment accident risk is about 100 times less than transporting spent nuclear fuel from the Canadian border to SRS (see Appendix E, Table E-9 of the FRR SNF EIS).

- Nonradiological accident risks (the potential for fatalities as a direct result of traffic accidents) present the greatest risks related to transporting HEU solutions, but no traffic fatalities would be expected. The per-shipment nonradiological accident risk for transporting HEU solutions would be about the same order of magnitude as that for transporting spent nuclear fuel estimated in the FRR SNF EIS (see Appendix E, Table E-10).

- Radiation doses to maximally exposed individuals would not cause a LCF.

- The consequences related to a most severe accident involving a high-temperature fire for a long duration would not cause a LCF.

9 Uncertainty and Conservatism in Estimated Impacts

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

In principle, one can estimate the uncertainty associated with each input or computational source and predict the resultant uncertainty in each set of calculations. Thus, one can propagate the uncertainties from one set of calculations to the next and estimate the uncertainty in the final, or absolute, result; however, conducting such a full-scale quantitative uncertainty analysis is often impractical and sometimes impossible, especially for actions to be initiated at an unspecified time in the future. Instead, the risk analysis is designed to ensure, through uniform and judicious selection of scenarios, models, and input parameters, that relative comparisons of risk among the various alternatives are meaningful. In the transportation risk assessment, this design is accomplished by uniformly applying shipments. The cumulative dose to this resident is calculated by assuming all shipments pass his or her home. The cumulative dose is calculated assuming that the resident is present for every shipment and is unshielded at a distance of about 30 meters (100 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 6 for all radioactive material transported, then the maximum dose to this resident, if all the materials were shipped via this route, would be about 7.4×10^{-5} millirem, with a risk of developing an LCF of about 4×10^{-8} or 1 chance in 25 million.

Table 5 Estimated Dose to Maximally Exposed Individuals Under Incident-Free Transportation Conditions

Receptor	*Dose to Maximally Exposed Individual*
Workers	
Crew member (truck driver)	5 rem per year [a]
Inspector	0.07 rem per event per hour of inspection
Public	
Resident (along the truck route)	9.8×10^{-7} rem per event
Person in traffic congestion	0.015 rem per event per half hour stop
Person at a rest stop/gas station	0.00033 rem per event per hour of stop
Gas station attendant	0.00083 rem per event

[a] Based on Occupational Safety and Health Administration regulatory limits.

The accident risk assessment and the impacts shown in Table 6 takes into account the entire spectrum of potential accidents, from the fender-bender to the extremely severe. To provide additional insight into the severity of accidents in terms of the potential dose to a MEI and the public, an accident consequence assessment has been performed for a maximum reasonably foreseeable hypothetical transportation accident.

Table 6 provides the estimated dose and risk to an individual and population from a maximum foreseeable truck transportation accident with the highest consequences under each alternative. The accident is assumed to be a severe impact in conjunction with a long fire duration.

Table 6 Estimated Dose to the Population and to Maximally Exposed Individuals Under the Maximum Reasonably Foreseeable Accident

Population Zone	*Maximum Likelihood of the Accident (per year)* [a]	*Meteorological Conditions* [b]	*Population* [c]		*MEI* [d]	
			Dose (person-rem)	*LCFs*	*Dose (rem)*	*LCFs*
Rural	6.6×10^{-12}	Neutral	0.70	4×10^{-4}	0.24	1×10^{-4}
		Stable	0.33	2×10^{-4}	0.012	7×10^{-6}
Suburban	4.6×10^{-12}	Neutral	15	9×10^{-3}	0.24	1×10^{-4}
		Stable	7.1	4×10^{-3}	0.012	7×10^{-6}
Urban	4.9×10^{-13}	Neutral	150	9×10^{-2}	0.24	1×10^{-4}
		Stable	71	4×10^{-2}	0.012	7×10^{-6}

LCF = latent cancer fatality

a The likelihoods shown are based on the given number of shipments using conditional probabilities from the Reexamination Study (NRC 2000). If conditional probabilities from the Modal Study (NRC 1987) were used, the likelihoods would range from 2.2 × 10-8 to 2.9 × 10-7.

b Neutral weather conditions were assumed to be Pasquill Stability Class D with a wind speed of 4 meters per second (8.8 miles per 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.

9.1 Uncertainties in Material Inventory and Characterization

The inventories and the physical and radiological characteristics are important input parameters to the transportation risk assessment. The 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.

9.2 Uncertainties in Route Determination

The route distances and population densities were derived from information pertaining to other routes due to the unavailability of TRAGIS. There is uncertainty, therefore, in whether the state-level population density data underestimates or overestimates what would have been derived using TRAGIS for the specific route. However, based on inspection and comparison with other routes that pass through the impacted states, the estimated population densities appear to be reasonable and representative of the route.

9.3 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).

9.4 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 2011).

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