APPENDIX C
DOSE METHODOLOGY AND IMPACTS

C.1 Introduction

This appendix presents the methodology, assumptions, data, and results for the potential impacts on individual workers and members of the public resulting from routine or normal operations and accidents from the Louisiana Energy Services (LES) proposed National Enrichment Facility (NEF), including a description of how radioactive material, such as uranium, results in radiation doses and a comparison of these doses to applicable standards.

The consequence of internal and external radiation exposure due to the deposition of energy from radioactive material in body tissues is represented as absorbed dose. Absorbed dose is quantified as energy absorbed per unit of tissue mass. The biological effect on individual tissues is estimated by multiplying the absorbed dose by a factor that accounts for the relative biological effect of differing types of radiation. This modified tissue dose is called dose equivalent. Dose equivalent can represent external radiation (i.e., radiation absorbed through the skin from a source external to the body) or internal radiation (i.e., radiation absorbed by internal tissues of the body due to inhalation or ingestion). The effect on the whole body from external and/or internal radiation is represented as a risk-weighted sum of the set of tissue dose equivalents. This dose, called the effective dose equivalent (EDE), can be integrated over a period of years to account for the accumulated effect from a single year's exposure. The time-integrated measure of effect for internal radiation is called the committed effective dose equivalent (CEDE). CEDEs are combined with dose estimates for external exposure to calculate a measure of effect for both exposure modes, called the total effective dose equivalent (TEDE) (ANL, 2004).

C.1.1 Regulatory Limits

Title 10, “Energy,” of the *U.S. Code of Federal Regulations* (10 CFR) Part 20 provides the regulatory limits for occupational doses and radiation dose for individual members of the public. For occupational doses, 10 CFR § 20.1201 states that licensees must limit the occupational dose to individual adults to an annual limit, which is the more limiting of:

- The TEDE being equal to 0.05 sievert (5 rems).
- The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 0.5 sievert (50 rems).

Additionally, the annual limits to the lens of the eye, to the skin of the whole body, and to the skin of the extremities are:

- A lens dose equivalent of 0.15 sievert (15 rems).
- A shallow-dose equivalent of 0.5 sievert (50 rem) to the skin of the whole body or to the skin of any extremity.

In addition to the annual occupational dose limits, 10 CFR § 20.1201 would limit the soluble uranium intake by an individual to 10 milligrams in a week because of chemical toxicity.

An explicit TEDE limit of 1.0 millisievert per year (100 millirem per year) from all sources is provided for individual members of the public. This limit includes both internal and external doses through all pathways (including food). External dose rates cannot exceed 0.02 millisievert (2 millirem) in any one hour. Further, LES would be subject to the generally applicable standards in 10 CFR § 20.1101 and 40 CFR Part 190. 40 CFR Part 190 requires that routine releases from uranium fuel-cycle facilities to the general environment would not result in annual doses exceeding 0.25 millisievert (25 millirem) to the whole body, 0.75 millisievert (75 millirem) to the thyroid, and 0.25 millisievert (25 millirem) to any other organ.

C.2 Pathway Assessment

Exposure to uranium processed by the proposed NEF could occur from routine operations as a result of small controlled releases to the atmosphere from the uranium enrichment process lines and decontamination and maintenance of equipment, releases of radioactive liquids to surface water, and direct radiation from the uranium material. Radioactive material released to the atmosphere, surface water, and groundwater is dispersed during transport through the environment and transferred to human receptors through inhalation, ingestion, and direct exposure pathways. Therefore, evaluation of impacts requires consideration of potential receptors, source terms, environmental transport, exposure pathways, and conversion of estimates of intake to dose.

Under the proposed action, the major source of occupational exposure would be expected to be from direct radiation from the uranium hexafluoride (UF_6) with the largest exposure source being the cylinders (empty and full) that hold the UF_6. These cylinders are as follows:

- Type 48Y cylinders containing either the feed material (natural UF_6) or the depleted uranium hexafluoride (DUF_6) called uranium byproduct cylinders (UBCs), or empty with residual material.

- Type 48X cylinders containing the feed material or empty with residual material.

- Type 30 product cylinders holding the enriched UF_6 for shipping to nuclear fuel manufacturers.

In addition to direct radiation, there could be the potential for serious internal exposure from long-term contact with UF_6 leaking from the process equipment and acute exposure resulting from accidents.

The major source of exposure to the general public would be expected to come from atmospheric releases. Such releases would be primarily controlled through the Technical Services Building and Separations Building gaseous effluent vent systems. The principal function of the gaseous effluent vent system is to protect both the operator during the connection/disconnection of UF_6 process equipment and the surrounding population and environment by collecting and cleaning all potentially hazardous gases from the plant prior to release to the atmosphere. In addition, the Centrifuge Test and Postmortem Facilities would have an exhaust filtration system that would serve the same purpose as the gaseous effluent vent system. The Technical Services Building heating, ventilation, and air-conditioning system would perform a confinement ventilation function for potentially contaminated areas in the building. Members of the public, if close enough, could be affected by direct radiation and skyshine (radiation reflected from the atmosphere).

The principal source for direct radiation offsite would be from the storage of UBCs filled with DUF_6 that could be stored within the site boundaries of the proposed NEF. Direct radiation and skyshine from the UF_6 within the Separations Building (i.e., the gaseous centrifuge cascades) would be undetectable because most of the direct radiation associated with this uranium would be almost completely absorbed by the heavy process lines, walls, equipment, and tanks that would be employed in the gaseous centrifuge cascades.

C.2.1 Receptors of Concern

LES determined distances to the site boundary using guidance from the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (NRC, 1983). The distance to the nearest resident was determined using global positioning system measurements. Figure C-1 shows the locations of the release points and locations of receptors of concern. The nearest resident is located 4,233 meters (2.6 mi) west of the proposed NEF gaseous effluent vent system stacks at a permanent residence. There are four industrial sites near the proposed NEF that are also considered for their potential exposures from gaseous releases, namely Wallach Concrete, Inc., Sundance Services, Inc., the Lea County Landfill, and Waste Control Specialists (WCS). The nearest resident is assumed to be present the entire year (8,766 hours), and workers are assumed to be present for an 8-hour workday, 5 days a week for 50 weeks a year (2,000 hours per year). Table C-1 presents the receptors and estimated distances.

Table C-1 Estimated Distances for Receptors of Concern

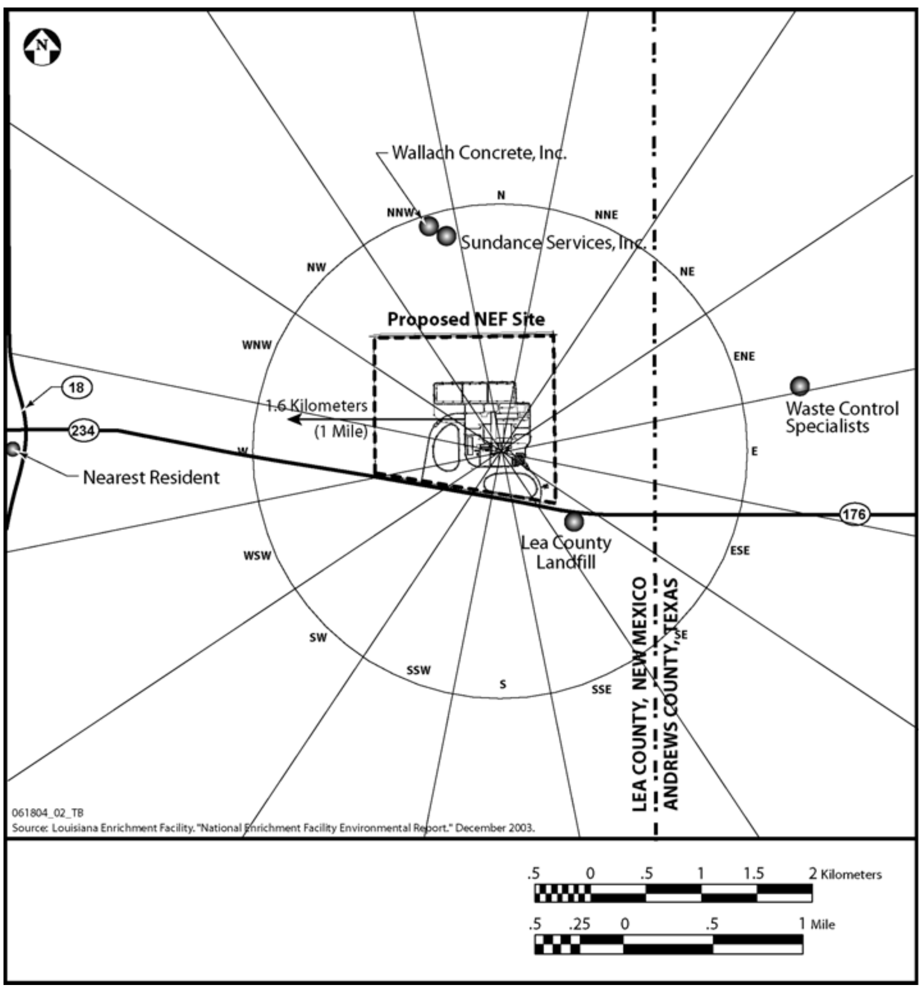

Figure C-1 Locations of Release Points and Individual Receptors (LES, 2005a)

Table C-1 Estimated Distances for Receptors of Concern

Receptor	Direction from Proposed NEF	Estimated Distance from Airborne Effluent Releases meters (miles)	Estimated Distance from UBC Storage Pad Edge to Receptor meters (miles)
Nearest Resident	West	4,233 (2.6)	—
Wallach Concrete, Inc.	North-Northwest	1,867 (1.2)	1,033 (0.6)
Sundance Specialists, Inc.	North-Northwest	1,706 (1.1)	885 (0.6)
Waste Control Specialists	East-Northeast	1,513 (0.9)	783 (0.5)
Lea County Landfill	Southeast	917 (0.6)	—

— No values given since receptor too distant or not in direct path.
Source: LES, 2005a.

The radiological assessment in this Environmental Impact Statement (EIS) determines impacts to a population within 80 kilometers (50 miles) and to a maximum exposed individual whose exposure would bound all foreseeable impacts related to the proposed NEF site operation. The total population within 80 kilometers (50 miles) is 94,758 people as calculated by SECPOP2000, a sector population, land fraction, and economic estimation program prepared for NRC based on Census 2000 data (NRC, 2003a`). Figure C-2 presents the population distribution, and Table C-2 presents population data for each of 16 downwind sectors at 10 distance intervals.

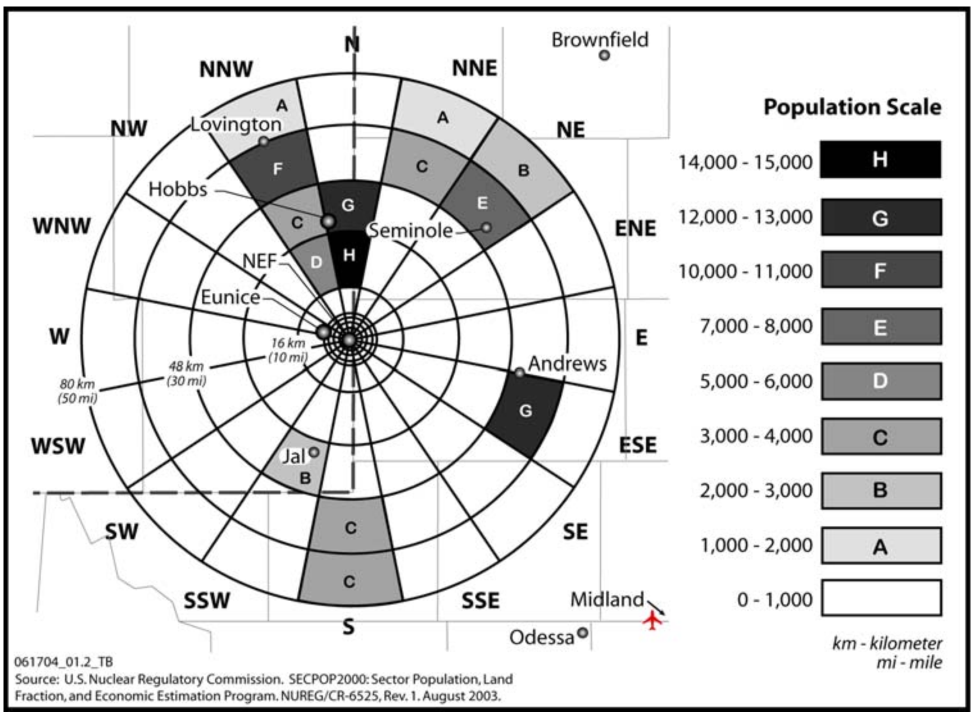

Figure C-2 Population within 80 Kilometers (50 Miles) of the Proposed NEF (NRC, 2003a)

Table C-2 Public Population in Sectors Surrounding the Proposed NEF

Sector	0-1 mi (0-1.6 km)	1-2 mi (1.6-3.2 km)	2-3 mi (3.2-4.8 km)	3-4 mi (4.8-6.4 km)	4-5 mi (6.4-8.1 km)	5-10 mi (8.1-16.1 km)	10-20 mi (16.1-32.2 km)	20-30 mi (32.2-48.3 km)	30-40 mi (48.3-64.4 km)	40-50 mi (64.4-80.5 km)
N	0	0	0	0	0	9	14,637	12,616	273	222
NNE	0	0	0	0	0	0	69	217	4,760	1,120
NE	0	0	0	0	0	0	49	995	7,464	2,809
ENE	0	0	0	0	0	0	7	430	972	46
E	0	0	0	0	0	0	7	45	351	41
ESE	0	0	0	0	0	0	0	105	12,351	60
SE	0	0	0	0	0	0	23	18	20	848
SSE	0	0	0	0	0	0	0	19	8	18
S	0	0	0	0	0	0	4	37	3,369	3,754
SSW	0	0	0	4	0	6	4	2,033	11	12
SW	0	0	0	0	0	17	12	3	1	3
WSW	0	0	0	0	15	34	9	13	2	8
W	0	0	11	53	2,099	484	13	2	4	21
WNW	0	0	0	0	104	35	20	0	9	8
NW	0	0	0	5	2	3	223	33	43	83
NNW	0	0	0	0	0	0	5,044	4,543	10,565	1,391

mi - mile.
km - kilometer.

C.2.2 Exposure Pathways Parameters

Guidance on acceptable exposure models for the pathways of concern has been published in NRC Regulatory Guide 1.109 (NRC, 1977a) and incorporated into a variety of computer codes. GENII v. 1.485 (Napier et al., 1988) is used to estimate collective radiation doses (person-rem) to members of the public resulting from post-accident inhalation and ingestion of soluble uranium compounds. The exposure pathways analyzed include inhalation of soluble uranium carried by wind, external radiation from radioactivity deposited on the ground downwind of the proposed NEF, and ingestion of contaminated food (produce, meat, and dairy products). The ingestion parameters used to estimate radiological doses to the public are described in Table C-3. For releases of uranium compounds, the northern sectors would have the highest collective doses because Hobbs, New Mexico, is a large population center in the prevailing downwind direction.

Table C-2 Public Population in Sectors Surrounding the Proposed NEF

Sector	0-1 mi (0-1.6 km)	1-2 mi (1.6-3.2 km)	2-3 mi (3.2-4.8 km)	3-4 mi (4.8-6.4 km)	4-5 mi (6.4-8.1 km)	5-10 mi (8.1-16.1 km)	10-20 mi (16.1-32.2 km)	20-30 mi (32.2-48.3 km)	30-40 mi (48.3-64.4 km)	40-50 mi (64.4-80.5 km)
N	0	0	0	0	0	9	14,637	12,616	273	222
NNE	0	0	0	0	0	0	69	217	4,760	1,120
NE	0	0	0	0	0	0	49	995	7,464	2,809
ENE	0	0	0	0	0	0	7	430	972	46
E	0	0	0	0	0	0	7	45	351	41
ESE	0	0	0	0	0	0	0	105	12,351	60
SE	0	0	0	0	0	0	23	18	20	848
SSE	0	0	0	0	0	0	0	19	8	18
S	0	0	0	0	0	0	4	37	3,369	3,754
SSW	0	0	0	4	0	6	4	2,033	11	12
SW	0	0	0	0	0	17	12	3	1	3
WSW	0	0	0	0	15	34	9	13	2	8
W	0	0	11	53	2,099	484	13	2	4	21
WNW	0	0	0	0	104	35	20	0	9	8
NW	0	0	0	5	2	3	223	33	43	83
NNW	0	0	0	0	0	0	5,044	4,543	10,565	1,391

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Table C-3 Ingestion Parameters Used in GENII to Calculate Collective Radiological Dose to the Public

Parameter Values for Consumption of Terrestrial Food

Food Type	General Population			
	Growing Time (days)	Yield kg/m² (lbs/ft²)	Holdup Time (days)	Consumption Rate kg/yr (lbs/yr)
Leafy Vegetables	90	1.5 (0.3)	14	15 (33)
Root Vegetables	90	4 (0.8)	14	140 (309)
Fruit	90	2 (0.4)	14	64 (141)
Grains/Cereals	90	0.8 (0.2)	180	72 (159)

Parameter Values for Consumption of Animal Products

Food Type	Consumption Rate kg/yr (lbs/yr)	Holdup Time (days)	Type	Diet Fraction	Growing Time (days)	Yield kg/m² (lbs/ft²)	Storage Time (days)
Beef	70 (154)	34	Stored Feed	0.25	90	0.8 (0.2)	180
			Fresh Forage	0.75	45	2 (0.4)	100
Poultry	8.5 (19)	34	Stored Feed	1	90	0.8 (0.2)	180
			Fresh Forage	---	---	---	---
Milk	230 (507)	3	Stored Feed	0.25	45	2 (0.4)	100
			Fresh Forage	0.75	30	1.5 (0.3)	0
Eggs	20 (44)	18	Stored Feed	1	90	0.8 (0.2)	180
			Fresh Forage	---	---	---	---

kg/m^2 - kilograms per square meter.
lbs/ft^2 - pounds per square feet.
km/yr - kilometers per year.
lbs/yr - pounds per year.
"Holdup Time" - the time between harvest and consumption of the food; this time includes processing, transportation, and storage of the food.

C.2.3 Airborne Release Parameters

LES provided information on release parameters at the proposed NEF (LES, 2005a). Table C-4 presents design information for each of the effluent release points. The primary release pathways for radioactivity discharged from the facility would be via the Technical Services Building and Separation Building gaseous effluent vent systems. Both of these exhaust stacks, as well as the Technical Services Building Confinement Ventilation System stack, would be located on the Technical Services Building roof. For the proposed NEF, 63 percent of the uranium discharged would be released via the Technical Services Building gaseous effluent vent system, with the remaining 37 percent estimated for the Separations

Building gaseous effluent vent system. Only trace amounts of uranium would be associated with the Technical Services Building Confinement Ventilation System and the Centrifuge Assembly Building Centrifuge Test and Postmortem Facility exhausts and, as such, would not be expected to release any detectable radioactivity.

Table C-4 Effluent Release Point Design Parameters

Release Point	Stack Exit Area m^2 (ft^2)	Exit Height m (ft)	Building Height m (ft)	Adjacent Building Height m (ft)	Exit Velocity m/sec (ft/min)	Exit Temperature
TSB GEVS	0.29 (3.14)	13 (42.6)	10 (32.8)	10 (32.8)	18.3 (3,600)	Room temp.
SB GEVS	0.13 (1.40)	13 (42.6)	10 (32.8)	10 (32.8)	23.4 (4,600)	Room temp.
CAB CT&PM	0.13 (1.40)	15 (49.2)	12 (39.4)	12 (39.4)	20.3 (4,000)	Room temp.
TSB CVS	0.29 (3.14)	13 (42.6)	10 (32.8)	10 (32.8)	20.3 (4,000)	Room temp.

TSB GEVS - Technical Services Building Gaseous Effluent Vent System.
SB GEVS - Separation Building Gaseous Effluent Vent System.
CAB CT&PM - Centrifuge Assembly Building; Centrifuge Test and Postmortem Facility.
TSB CVS - Technical Services Building Confinement Ventilation System.
m -meter.
m^2 - square meter.
ft - feet.
m/sec - meters per second.
ft/min - feet per minute.
Source: LES, 2005a.

The primary component of atmospheric dispersion is mechanical mixing produced by temperature and wind velocity gradients. For projected normal operational releases, the methods of Regulatory Guide 1.111 (NRC, 1977b) are used to estimate concentrations of released material at a range of distances and directions from the release point. These methods use the Gaussian plume dispersion model that is implemented in the XOQDOQ computer code and was applied in this analysis (Sagendorf et al., 1982).

The atmospheric dispersion model XOQDOQ is intended to provide estimates of atmospheric transport and dispersion of gaseous effluents in routine releases from nuclear facilities. XOQDOQ is based on the theory that material released to the atmosphere will be normally distributed (Gaussian distribution) about the plume centerline. In predicting concentrations for longer time periods, the horizontal plume distribution is assumed to be evenly distributed within the directional sector, the so-called sector average model. A straight-line trajectory is assumed between the point of release and all receptors.

The atmospheric dispersion modeling results indicate that the maximum annual average air concentrations would occur at the north sector site boundary approximately 1,014 meters (0.6 mile) north of the Technical Services Building stack with an elevated atmospheric dispersion factor (P/Q) of 2.3×10^{-6} seconds per cubic meter. Therefore, the individual assumed to be located at the northern sector boundary is the maximally exposed individual for the air pathway. The atmospheric dispersion modeling predicts that the annual average air concentration of releases beyond the site boundary are all less than the northern sector boundary. Concentrations per unit release quantity (i.e., **P**/Q) predicted by using this model for the other receptors of concern are summarized in Table C-5.

Table C-5 Summary of Atmospheric Dispersion Factors

Receptor	Location	TSB **P**/Q (s/m^3)	SB **P**/Q (s/m^3)	Exposure Time (hours)
Nearest Resident	4,233 m (2.6 mi) west	1.4×10^{-7}	1.4×10^{-7}	8,766 hours
Lea County Landfill Worker	917 m (0.6 mi) southeast	1.0×10^{-6}	1.0×10^{-6}	2,000 hours
Wallach Concrete, Inc.	1,867 m (1.2 mi) north-northwest	1.1×10^{-6}	1.3×10^{-6}	2,000 hours
Sundance Services, Inc.	1,706 m (1.1 mi) north-northwest	1.3×10^{-6}	1.4×10^{-6}	2,000 hours
Waste Control Specialists	1,513 m (0.9 mi) east-northeast	4.9×10^{-7}	5.0×10^{-7}	2,000 hours

TSB - Technical Services Building.
SB - Separations Building.
s/m^3 - seconds per cubic meter.
m - meter.
mi - mile.
To convert seconds per cubic meter (s/m^3) to seconds per cubic foot (s/ft^3), multiply by 0.028.

C.3 Radiation Exposures from Normal Operation

Members of the public may be exposed to radioactive material dispersed in the environment through inhalation of air, ingestion of drinking water, ingestion of terrestrial foods and animal products, inadvertent ingestion of soil, and direct irradiation from nuclides deposited on the ground or present in surface water.

LES estimated the expected isotopic release mix resulting from the estimated annual release of 10 grams (0.022 pound) of uranium as shown in Table C-6 (LES, 2005a; LES, 2004a). These values of gaseous effluent are based on operational experience at the Urenco Capenhurst Limited enrichment facility in the United Kingdom. For purposes of the radiological impact analysis, the bounding annual releases to the atmosphere from the proposed NEF site are estimated to be 8.9×10^{6} becquerels (240 microcuries). The 8.9×10^{6} becquerels (240 microcuries) is a bounding annual release estimate based upon a prior NRC estimate for a 1.5 million separative work unit (SWU) plant (NRC, 1994). The bounding annual release would also be conservative because it is approximately 35 times larger than the expected gaseous source term of 253.1 kilobecquerels per year (6.84 microcuries per year) as identified in Table C-6. The proposed NEF design is based upon the prior design but with a doubling of the enrichment capacity to 3 million SWU. The expected isotopic release resulting from the bounding annual release of 8.9×10^{6} becquerels (240 microcuries) of uranium from the Technical Services Building and Separations Building Gaseous Effluent Vent Systems is also shown in Table C-6. For gaseous effluents resulting from the sublimation of UF_6, no significant amount of radioactive particulate material (uranium or its radioactive decay daughters) would be expected to be introduced into the process ventilation system and released to the environment after Gaseous Effluent Vent System filtration (LES, 2005a).

Table C-6 Annual Effluent Releases

Radionuclide	Estimated Releases[a]		Bounding Releases	
	TSB GEVS kBq/yr (:Ci/yr)	SB GEVS kBq/yr (:Ci/yr)	TSB GEVS kBq/yr (:Ci/yr)	SB GEVS kBq/yr (:Ci/yr)
Uranium-234	77.7 (2.10)	45.5 (1.23)	2,738 (74.0)	1,591 (43.0)
Uranium-235	3.59 (0.097)	2.11 (0.057)	125.8 (3.4)	74.0 (2.0)
Uranium-236	0.48 (0.013)	0.30 (0.008)	17.0 (0.46)	11.1 (0.3)
Uranium-238	77.7 (2.10)	45.5 (1.23)	2,738 (74.0)	1,591 (43.0)
Total	159.5 (4.31)	93.6 (2.53)	5,619 (151.86)	3,267 (88.3)

[a] Source: LES, 2005a. Equivalent to 10 grams (0.022 pound) uranium.
TSB GEVS - Technical Services Building Gaseous Effluent Vent System.
SB GEVS - Separation Building Gaseous Effluent Vent System.
kBq/yr - kilobecquerels per year.
:Ci/yr - microcuries per year.

C.3.1 Exposure to Members of the Public

Radioactive material would be released to the atmosphere from the proposed NEF site through stack releases from the Technical Services Building Gaseous Effluent Vent System, Separations Building Gaseous Effluent Vent System, and from the potential resuspension of contaminated soil within the Treated Effluent Evaporative Basin. While a member of the public would not be expected to spend a significant amount of time at the site boundary closest to the UBC Storage Pad, this possibility is included in this impact assessment. The expected exposure pathways include inhalation of air and direct exposure from material deposited on the ground. In addition to these expected routes of exposure, members of the public may also consume food containing deposited radionuclides and inadvertently ingest resuspended soil from the ground or on local sources of food (e.g., leafy vegetables, carrots, potatoes, and beef from nearby grazing livestock). Potential effective dose equivalents for the maximally exposed adult individuals of Table C-5 and for the population are provided in Table C-7. The general population within 80 kilometers (50 miles) of the proposed NEF would receive a collective dose of 0.014 person-rem, equivalent to 8.4×10^{-6} latent cancer fatalities from normal operations.

LES calculated the dose isopleths for the case of a 30-year stockpile of UBCs with 2,000 hours of exposure as shown in Figure C-3 (LES, 2005a). The greatest dose from direct radiation would be for a receptor on the northern site boundary at centerline of the northern edge of the UBC Storage Pad. Because the nearest resident would be 4,233 meters (2.6 miles) from the UBC Storage Pad, with a reduction in dose rates on the order of 6×10^{-8} due to distance alone, the potential impact of direct radiation from stored cylinders on the surrounding population is considered to be negligible. However, three industrial sites would be in direct line-of-sight and within 1.6 kilometers (1 mile) of the UBC Storage Pad. Using the 0.2-millisievert (20-millirem) isopleths from Figure C-3, the direct radiation for these receptors is estimated for reduction in dose versus distance for 2,000 hours per year and provided in Table C-7.

It is possible that contaminated soil at the bottom of the Treated Effluent Evaporative Basin could be resuspended into the air. To analyze the potential for health impacts due to resuspension, the NRC staff assumed that 0.57 kilograms (1.3 pounds) per year of uranium for 30 years would settle into the Treated Effluent Evaporative Basin soil (LES, 2005a). As a result, 27.4×10^{6} becquerels (7.4 millicuries) of uranium was assumed to accumulate in the basins. The contaminated soil would have a resuspension factor of 4×10^{-6} per hour. This could result in an additional annual effective dose of 1.7×10^{-6} millisieverts (1.7×10^{-4} millirem) to the nearest resident, with the largest offsite dose at the south site boundary of 1.7×10^{-5} millisieverts (1.7×10^{-3} millirem) (LES, 2005a). The resuspension factor for soils could be as high as 9×10^{-5} per hour for areas that are fairly open to the prevailing winds (DOE, 1994). Because the Treated Effluent Evaporative Basin would be excavated below ground with a net or other suitable material covering the basin, the ability of prevailing winds to resuspend contaminated soils would be expected to be less than that assumed by LES, and the resulting impacts are considered conservative.

Normal operations at the proposed NEF would have SMALL impacts to public health. The total annual dose from all exposure pathways would be significantly less than the regulatory requirement of 1 millisievert (0.1 rem) of 10 CFR § 20.1301. The most significant impact is from direct radiation exposure

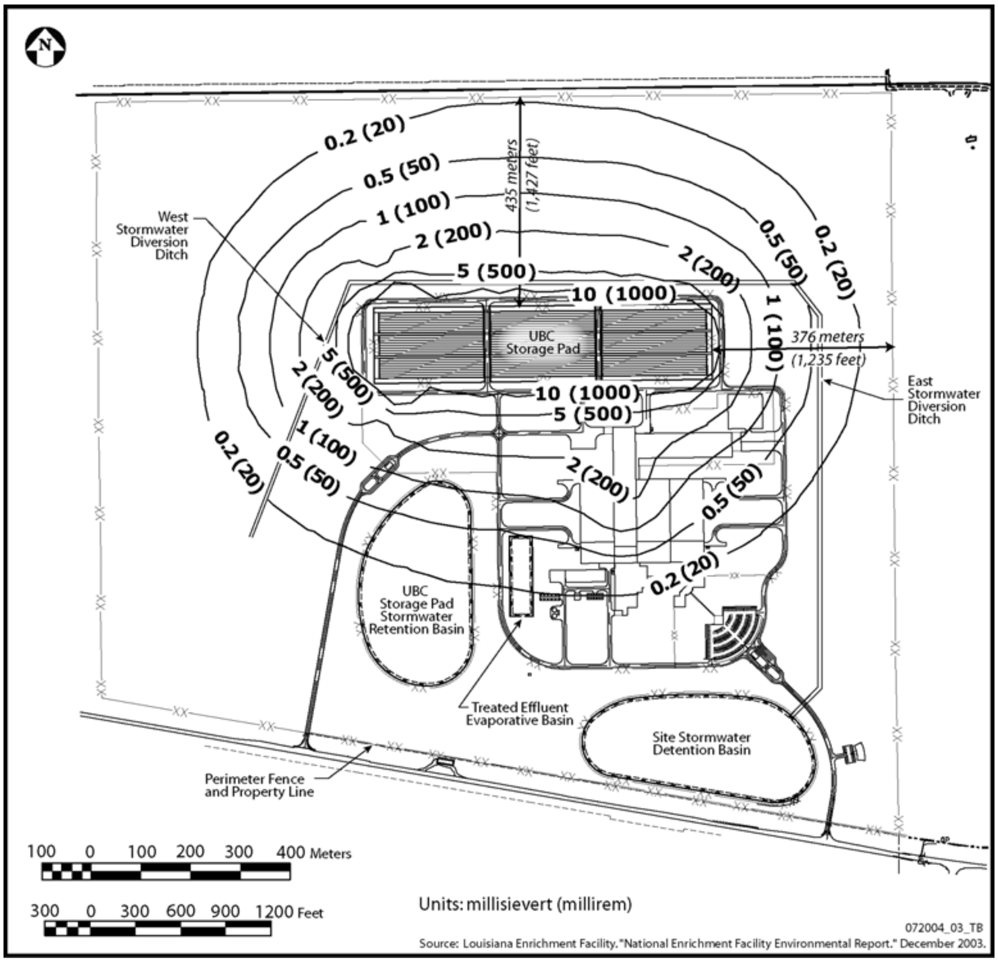

Figure C-3 2,000-Hour Dose Isopleths for a 30-Year Stockpile of Uranium Byproduct Cylinders (LES, 2005a)

to receptors close to the UBC Storage Pad (filled and empty Type 48Y cylinders). The results are based on conservative assumptions, and it is anticipated that actual exposure levels will be less than those presented in Table C-7.

Table C-7 Radiological Impacts to Members of the Public Associated With Operation of the Proposed NEF

Receptor	Location from Proposed NEF Stacks	Airborne Pathway CEDE	Direct Radiation [a]	Total Annual Impact
Population, Person-Sv (person-rem)	Within 80.5 km (50 mi) of Proposed NEF	1.4×10^{-4} (1.4×10^{-2})	N/A	1.4×10^{-4} (1.4×10^{-2})
Highest Boundary (Stack Releases), mSv (mrem)	Northern Boundary 1,010 m (0.6 mi)	5.3×10^{-5} (5.3×10^{-3})	0.189 (18.9)	0.189 (18.9)
Nearest Resident [b], mSv (mrem)	4,233 m (2.6 mi) west	1.3×10^{-5} (1.3×10^{-3})	N/A	1.3×10^{-5} (1.3×10^{-3})
Lea County Landfill Worker, mSv (mrem)	917 m (0.57 mi) southeast	1.9×10^{-5} (1.9×10^{-3})	N/A	1.9×10^{-5} (1.9×10^{-3})
Wallach Concrete, Inc. mSv (mrem)	1,867 m (1.16 mi) north-northwest	2.2×10^{-5} (2.2×10^{-3})	0.021 (2.1)	0.021 (2.1)
Sundance Services, Inc., mSv (mrem)	1,706 m (1.06 mi) north-northwest	2.6×10^{-5} (2.6×10^{-3})	0.026 (2.6)	0.026 (2.6)
Waste Control Specialists, mSv (mrem)	1,513 m (0.94 mi) east-northeast	9.3×10^{-6} (9.3×10^{-4})	0.021 (2.1)	0.017 (1.7)

[a] Direct radiation from the maximum number of UBCs over the lifetime of the proposed NEF.
[b] Includes airborne contamination from the Treated Effluent Evaporative Basin.
Sv - sievert.
mSv - millisievert.
mrem - millirem.
km - kilometer.
mi - mile.

For comparison to the effects from a similar facility, the Urenco enrichment facility in Capenhurst, United Kingdom (total capacity of 2.96 million SWU), can be considered. The Ministry of Agriculture, Fisheries and Food of the Scottish Environment Protection Agency monitors gaseous and liquid emissions from the Capenhurst facility and annually estimates radiological impacts. According to available reports from 1998 through 2002, a radiation dose to the maximum exposed individual was estimated to be less than 0.005 millisievert (0.5 millirem) per year for ingestion of terrestrial food contaminated via gaseous effluents (LES, 2005a). The highest radiation dose to the maximum exposed individual was estimated to be less than 0.011 millisievert (1.1 millirem) per year for ingestion of liquids being released from the Capenhurst site, assuming children played near the brook along the site and ingested water and sediment (LES, 2004a). Therefore, the proposed NEF will have less of an impact to the public than the Capenhurst facility because, unlike at Capenhurst, members of the public would not be directly exposed to liquid discharges or by the site boundary for extended periods of time. More importantly, both sets of annual doses are significantly below the U.S. regulatory requirement of 1 millisievert (100 millirem) (10 CFR Part 20) or 0.25 millisievert (25 millirem) for uranium fuel-cycle facilities (40 CFR Part 190).

C.3.2 Occupational Exposure Due to Normal Operation

The regulations of 10 CFR Part 20 not only require an NRC licensee to have an effective radiation protection program (10 CFR § 20.1101) but also require annual reports on the facility's occupational exposures (10 CFR § 20.2206) that the NRC gathers, evaluates, and presents in new volumes of NUREG-0713. By analyzing the sources of radiation and having an effective and efficient radiation protection program to determine the potential occupational dose rates, a licensee can determine whether any special administrative controls need to be applied to a specific individual or site-wide to maintain workers below the regulatory and company-set exposure limits. In addition to estimates of the occupational exposure, a comparison to the historical exposure data from similar facilities can demonstrate the effectiveness of the administrative controls (i.e., the radiation protection program) and/or the level of impacts that would be expected from a similar facility. In addition to the occupational exposure data from NUREG-0713 for the current U.S. enrichment facilities, the historical data from the Urenco Almelo and Capenhurst facilities would also be used for a comparison of impacts.

Tables C-8 and C-9 present the estimated occupational dose rates and annual exposures for various locations or buildings within the proposed NEF site and representative workers, respectively. Sections 4.7.6 and 4.8.1 of the Safety Analysis Report (LES, 2005b) describe the personnel-monitoring program for internal exposure from intake of soluble uranium. An annual administrative limit of 10 millisieverts (1,000 millirems) that includes external radiation sources and internal exposure from no more than 10 milligrams of soluble uranium in a week would be applied for comparison with the LES occupational exposure results, the historical data for past occupational exposures at U.S. enrichment facilities are shown in Table C-10, while comparisons to historical data for European and U.S. enrichment facilities are shown in Tables C-11 and C-12.

The estimated occupational dose rate for an empty used UF_6 cylinder is higher than for a full UF_6 cylinder for two reasons. First, after UF_6 is vaporized and removed from a cylinder, the radioactive uranium daughter products that build up due to the radioactive decay of uranium collect at the bottom and form a "heel." The radiation emitted from the uranium daughter products consist of a greater quantity of gamma radiation than that produced by only uranium. Second, uranium is a good shield material for gamma radiation. When the cylinder is full of UF_6, the uranium daughters are distributed throughout the cylinder and must pass through a significant amount of uranium (thus can be stopped or absorbed by the uranium). It is only the uranium daughters near the inner surface of the cylinder that can readily escape from the cylinder and contribute to a nearby person's radiation exposure. Because the empty cylinder no longer has the high shielding capability of the UF_6 and the heel concentrates the more highly radioactive uranium daughters near the inner cylinder surface, the radiation levels of the empty UF_6 cylinders are higher than the levels of full cylinders.

Table C-8 Estimated Occupational Dose Rates for Various Locations or Buildings Within the Proposed NEF

Location	Dose Rate, mSv/hr (mrem/hr)
Plant General Area (Excluding Separations Building Modules)	< 0.0001 (< 0.01)
Separations Building Module - Cascade Halls	0.0005 (0.05)
Separations Building Module - UF_6 Handling Area and Process Services Area	0.001 (0.1)
Empty Used UF_6 Shipping Cylinder	0.1 (10.0) on contact 0.010 (1.0) at 1 meter (3.3 feet)
Full UF_6 Shipping Cylinder	0.05 (5.0) on contact 0.002 (0.2) at 1 meter (3.3 feet)

mSv/hr - millisieverts per hour; mrem/hr - millirems per hour.
Source: LES, 2005a.

Table C-9 Estimated Occupational Annual Exposures for Various Occupations Within the Proposed NEF

Position	Annual Dose Equivalent[a] mSv (mrem)
General Office Staff	< 0.05 (< 5.0)
Typical Operations and Maintenance Technician	1 (100)
Typical Cylinder Handler	3 (300)

[a] Average worker exposure at Urenco Capenhurst facility during 1998 through 2002 was approximately 0.2 mSv (20 mrem).
mSV - millisievert; mrem - millirem.
Source: LES, 2005a.

Table C-10 Annual CEDE and TEDE for Uranium Enrichment Plants Within the United States for 1997 - 2002

Year	Number with Meas. CEDE	Collective CEDE (person-rem)	Avg. Meas. CEDE (rem)	Number Meas. Exposure	Total Number Monitored	Number with Meas. Dose	Total Collective TEDE (person-rem)	Avg. Meas. TEDE (rems)
1997	36	0.314	0.01	5,705	6,296	591	30.003	0.051
1998	58	0.242	0	5,713	6,150	437	23.621	0.054
1999	22	0.445	0.02	5,119	5,559	440	20.124	0.046
2000	69	0.587	0.01	4,015	5,016	1002	28.356	0.028
2001	53	0.108	0	3,670	4,015	345	10.325	0.030
2002	40	0.208	0.01	3,190	3,683	493	20.601	0.042

To convert rem to sievert, multiply by 0.01.
Sources: NRC, 1998a; NRC, 1999; NRC, 2000; NRC, 2001a; NRC, 2002; NRC, 2003b.

Table C-11 Comparison of Annual Maximum TEDE for Capenhurst and U.S. Enrichment Facilities

Year	Capenhurst Maximum TEDE Sv (rem)	Highest Whole Body Doses at U.S. Enrichment Facilities Sv (rem) [a]
1998	0.0031 (0.31)	0.0025-0.005 (0.25-0.5)
1999	0.0022 (0.22)	0.0025-0.005 (0.25-0.5)
2000	0.0028 (0.28)	0.001-0.0025 (0.1-0.25)
2001	0.0027 (0.27)	0.001-0.0025 (0.1-0.25)
2002	0.0023 (0.23)	0.0025-0.005 (0.25-0.5)

[a] NUREG-0713 provides 12 dose ranges and the respective number of workers with whole body doses in that range. The value given in this column is the highest whole body dose range for that year.
[b] Five-year average (1998-2002) using the average TEDE from Table 4.13.2.2-1 of the Safety Analysis Report.
Sv - Seivert.
Sources: LES, 2005a; LES, 2005b; NRC, 1999; NRC, 2000; NRC, 2001a; NRC, 2002; NRC, 2003b.

Table C-12 Comparison of Annual Average TEDE for Almelo, Capenhurst, and U.S. Enrichment Facilities

Almelo TEDE Sv (rem)	Capenhurst TEDE Sv (rem)	U.S. Enrichment Facilities Sv (rem)
0.0004 (0.04)	0.0002 (0.02)	0.0004 (0.04) [a]

[a] Five-year average (1998-2002) using the average TEDE from Table 4.13.2.2-1 of the Safety Analysis Report.
Sv - Seivert.
Sources: LES, 2005a; LES, 2005b, NRC, 1999; NRC, 2000; NRC, 2001a; NRC, 2002; NRC, 2003b.

The LES occupational exposure analysis, as collaborated by the historical exposure data, demonstrates that a properly administered radiation protection program at the proposed NEF should maintain the radiological occupational impacts well below the regulatory limits of 10 CFR § 20.1201. Therefore, the impacts from occupational exposure at the proposed NEF would be considered SMALL.

C.4 Public and Occupational Health Impacts from Accidents During Operations

The operation of the proposed NEF would involve risks to workers, the public, and the environment from potential accidents. The regulations in 10 CFR Part 70, Subpart H, "Additional Requirements for Certain Licensees Authorized to Possess a Critical Mass of Special Nuclear Material," require that each applicant or licensee evaluate, in an Integrated Safety Analysis Summary, its compliance with certain performance requirements. The purpose of this section of this EIS is to summarize the methods and results used to independently evaluate the consequences of potential accidents identified in LES's Integrated Safety Analysis. The accidents evaluated are a representative selection of the types of accidents that are possible at the proposed NEF.

C.4.1 Accident Analysis Methodology

The analytical methods used in this consequence assessment are based on NRC guidance for analysis of nuclear fuel-cycle facility accidents (NRC, 1990; NRC, 1991; NRC, 1998b; NRC, 2001b). With the exception of the criticality accident, the hazards evaluated involve the release of UF_6 vapor from process systems that are designed to confine UF_6 during normal operations. As described below, UF_6 vapor poses a chemical and radiological risk to workers, the public, and the environment. LES has committed to various preventive and mitigative measures to significantly reduce these risks.

C.4.1.1 Selection of Representative Accident Scenarios

The Safety Analysis Report and Emergency Plan (LES, 2005b; LES, 2004b) describe potential accidents that could occur at the proposed NEF. Accident descriptions are provided for two groups according to the severity of the accident consequences: high-consequence events and intermediate-consequence events. The accident types are summarized in the Emergency Plan as follows:

<u>High-Consequence Events</u>

- Natural phenomena.
  - Earthquake.
  - Tornado.
  - Flood.
- Inadvertent nuclear criticality.
- Fires propagating between areas.
- Fires involving excessive transient combustibles.
- Heater controller failure.
- Overfilled cylinder heated to ambient temperature.
- Product liquid sampling autoclave heater failure followed by reheat.
- Open sample manifold purge valve and blind flange.
- Pump exhaust plugged (worker).
- UF_6 subsampling unit hot box heater controller failure.
- Empty UF_6 cold trap (UF_6 release).
- Cylinder valve/connection failure during pressure test.
- Chemical dump trap failure.
- Worker evacuation.

<u>Intermediate-Consequence Events</u>

- Carbon trap failure.
- Pump exhaust plugged (public).
- Spill of failed centrifuge parts.
- Dropped contaminated centrifuge.
- Fire in ventilated room.

The NRC staff selected a subset of the potential accident scenarios for detailed evaluation to encompass the range of possible accidents. The accident scenarios selected vary in severity from high to low consequence events and include accidents initiated by natural phenomena, operator error, and equipment failure. The accident scenarios evaluated are as follows:

- Generic Inadvertent Nuclear Criticality.
- Hydraulic Rupture of a UF_6 Cylinder in the Blending and Liquid Sampling Area.
- Natural Phenomena Hazard–Earthquake.
- Fire in a UF_6 Handling Area.
- Process Line Rupture in a Product Low-Temperature Takeoff Station.

C.4.1.2 Source-Term Methodology

NRC staff evaluated the chemical and radiological hazard to workers, the public and the environment from accidental releases of UF_6 vapor at the facility. For most accidents, the UF_6 vapor is assumed to escape its primary confinement system and enter an occupied room at the proposed NEF. It is assumed that UF_6 would mix instantaneously with the air in the room.

For a constant release rate of UF_6, the time-dependent concentration, C(t), of UF_6 in a room or workshop at the proposed NEF would be (NRC, 1990):

$$\frac{dC(t)}{dt} = \frac{R}{V'} - \frac{Q_v f_v C(t)}{V'} \qquad \text{Eq. C-1}$$

where R = constant UF_6 release rate, grams/second
V' = k×f×V, the effective room volume, cubic meters
V = actual room volume, cubic meters
k = mixing efficiency (from National Fire Protection Association 69 [NFPA, 2002], Appendix D), unitless
f = room free air fraction, unitless
Q_v = room ventilation rate, cubic meters per second
f_v = the fraction of Q_v exhausted to the atmosphere (1-f_v is recycled back into the room)
t = time elapsed since start of release, seconds

The values of mixing efficiency, k, and room free-air fraction, f, are assumed to be 0.3 and 0.8, respectively. The mixing efficiency is conservatively based on Table D-1 of National Fire Protection Association 69 (NFPA, 2002), and is for ventilation systems with forced-air supplies and single exhaust openings comprised of grills and registers. The value of 0.8 is assumed to account for the volume of equipment that replaces free air inside the facility. Room volumes and ventilation flow rates were provided by LES (LES, 2004c). The fraction of air exhaust is 10 percent, which is consistent with the heating, ventilation, and air-conditioning descriptions in Chapters 3 and 4 of the Safety Analysis Report (LES, 2005a).

A solution to Equation C-1 is:

$$C_1(t) = \frac{R}{Q_v f_v}\left[1 - e^{-\frac{Q_v f_v}{V'}t}\right] \qquad \text{Eq. C-2}$$

Equation C-2 defines the concentration, $C_1(t)$, during the period that UF_6 is released at a steady-state rate, R, into a room. After T_1 = 30 minutes, it is assumed that either the entire material at risk would be released or the release would be stopped when operators intervene. The assumption that operators or affected individuals downwind would respond within 30 minutes is consistent with conservative self-protective criteria used by NRC to evaluate emergency preparedness (NRC, 1988). After T_1 = 30 minutes, the room would be ventilated until UF_6 is cleared from the room and exhausted to the environment. The room concentration, $C_2(t)$, after all the material escapes to the room, or the release is stopped is:

$$C_2(t) = \frac{R}{Q_v f_v}\left[1 - e^{-\frac{Q_v f_v T_1}{V'}}\right] e^{-\frac{Q_v f_v}{V'}t} \qquad \text{Eq. C-3}$$

For the seismic event, LES has proposed safety-related equipment (i.e., Items Relied on for Safety) that shut down the heating, ventilation, and air-conditioning systems in certain process areas. With no forced ventilation, the primary means by which UF_6, compound uranyl fluoride (UO_2F_2) particulate matter, and hydrogen fluoride vapor enters the environment would be from small cracks and openings in the building.

The volumetric leak rate from small cracks and openings in a building is calculated by evaluating Poiseuille's Law (Baker et al., 1987):

$$Q_L = -\left(\frac{12\eta dL_S}{C\rho W}\right) + \sqrt{\left(\frac{12\eta dL_S}{C\rho W}\right)^2 + \frac{C_{p,a} v^2 W^2 L_S^2}{C}} \qquad \text{Eq. C-4}$$

where Q_L = volumetric leak rate, cubic meters per second
L_s = perimeter length of all exterior doors, meters
W = width of the opening between door and frame, meters
0 = coefficient of viscosity of air = 1.81×10^{-5} N-seconds per square meter at T = 20°C (68°F)
d = thickness of doors, meters
C = 1.5
D = density of air = 1.183 kilograms per cubic meter at T = 25°C (77°F)
v = wind speed, meters per second

The value of $C_{p,a}$ depend on the location of the door or opening relative to the direction of the wind (Blevins, 2003):

where $C_{p,a}$ = 0.9 for windward side of the building
$C_{p,a}$ = -0.3 for leeward side of the building
$C_{p,a}$ = -0.4 for building sides orthogonal to the wind direction

For this assessment, each exterior door in affected process areas of the building is assumed to have a W = 0.2 centimeter (.08 inch) opening around both sides and the top, and a W = 0.3 centimeter (.12 inch) opening at the bottom. The thickness of all doors, d, is estimated to be 5 centimeters (2 inches). The perimeter length of doors is estimated from drawings in the Safety Analysis Report (LES, 2005a).

The wind speed, v, assumed for the building leakage calculations was chosen with consideration of the wind speed and stability class assumed in the derivation of the maximum atmospheric dispersion factor, **P**/S. The highest **P**/S calculated for the controlled area boundary is 5.4×10^{-5} seconds per cubic meter. With corrections for building wake and low wind speed plume meander, the wind speed for F class stability conditions for which a **P**/S = 5.4×10^{-5} seconds per cubic meter would be derived is 1.75 meters per second (5.7 feet per second). Therefore, a bounding value of v = 2 meters per second (6.6 feet per second) is used to estimate building leakage.

Solid UO_2F_2 produced by the reaction of UF_6 with water vapor (i.e., humidity) forms a fine powder that will settle by gravity. Therefore, in addition to removal by exfiltration through door cracks to the environment, solid UO_2F_2 will also be removed from the air by settling on the floor and equipment of the affected process area. The concentration in the building is calculated as:

$$C_L(t) = C_{L,O}\, e^{-\frac{1}{V'}(Q_L + v_d A)t} \qquad \text{Eq. C-5}$$

where v_d = settling velocity of UO_2F_2 particles in air, meters per second
A = floor area of the affected process area, square meters

From Table 12.4 of DOE/TIC-27601 (DOE, 1984), the settling velocity of fine uranium compounds estimated to be approximately 0.0001 centimeter per second (0.0002 feet per minute). The floor areas of the affected process areas are estimated from drawings in the Safety Analysis Report (LES, 2005a).

C.4.1.3 NRC Performance Requirements

The performance requirements in 10 CFR Part 70, Subpart H, define acceptable levels of risk of accidents at nuclear fuel-cycle facilities, such as the proposed NEF. The regulations in Subpart H require that LES reduce the risks of credible high-consequence and intermediate-consequence events. Threshold consequence values that define the high- and intermediate-consequence events for the proposed NEF are described in Table C-13 (LES, 2005a).

Table C-13 Definition of High- and Intermediate-Consequence Events at the Proposed NEF

Receptor	Intermediate Consequence	High Consequence
Worker - Radiological	> 25 rem (0.25 Sv)	> 100 rem (1 Sv)
Worker - Chemical (10-minute exposure)	> 19 mg U/m^3 ***** > 78 mg HF/m^3	> 146 mg U/m^3 ***** > 139 mg HF/m^3
Environment at the Restricted Area Boundary	> 5.4 mg U/m^3 or 24-hour average release greater than 5,000 times the values in Tables 2 of Appendix B of 10 CFR Part 20	N/A
Individual at the Controlled Area Boundary - Radiological	> 5 rem (0.05 Sv)	> 25 rem (0.25 Sv)
Individual at the Controlled Area Boundary - Chemical (30-minute exposure)	> 2.4 mg U/m^3 > 0.8 mg HF/m^3	> 13 mg U/m^3 > 28 mg HF/m^3

Sv - sievert; HF - hydrogen fluoride; U - uranium.
mg - milligram.
m^3 - cubic meters.
* Limits on uranium intake are also defined for workers in the immediate proximity of the release. These limits are 10 mg and 40 mg uranium for intermediate and high consequence events, respectively.

C.4.1.4 Consequence Assessment Methodology for Acute Health Effects

Accident consequences were evaluated for the proposed NEF facility worker, the environment outside the restricted area boundary, an individual at the controlled area boundary, and the public beyond the controlled area boundary. As stated above, the analytical methods used in this consequence assessment are based on NRC guidance for analysis of nuclear fuel-cycle facility accidents (NRC, 1990; NRC, 1991; NRC, 1998b; NRC, 2001b).

<u>Facility Worker Uranium Intake and Exposure to Hydrogen Fluoride</u>

The accident consequences to a facility worker include the risks of toxicological effects of uranium intake, radiation dose from uranium intake, and exposure to hydrogen fluoride concentration in air. The amount of uranium a facility worker could inhale (uranium intake) is calculated by assuming the worker is exposed to $C_1(t)$ until T_1 = 10 minutes after the start of the release (LES, 2005a). By T_1 = 10 minutes, a worker is assumed to successfully escape the affected room. The staff calculated uranium concentration for comparison with the proposed levels in Table C-13. For a 10-minute exposure period, uranium concentration limits are more restrictive than the intake limits that are described in the footnote to Table C-13. The worker is assumed to inhale at a constant breathing rate of 3.33×10^{-4} cubic meters per second (20 liters per minute), which is consistent with the breathing rate used by NRC in 10 CFR Part 20, Appendix B, for Reference Man performing "light work." Similarly, the hydrogen fluoride concentration to which a facility worker could be exposed is calculated by evaluating the time-averaged hydrogen fluoride concentration during the first T_1 =10 minutes.

For the uranium intake and hydrogen fluoride exposure calculations, it is assumed that sufficient moisture (i.e., humidity) is present in the room to completely convert released UF_6 gas to UO_2F_2 particulate matter and hydrogen fluoride vapor. This assumption results in a conservative estimate of the concentration of hydrogen fluoride vapor that would be present in both the affected room of the proposed NEF and downwind.

Restricted Area Boundary 24-Hour Average Uranium Concentration

In accordance with 10 CFR Part 70, Subpart H, LES must reduce the environmental risks of accidents. The environmental consequences of accidents are evaluated at the restricted area boundary. At the proposed NEF, the restricted area boundary would be a fenced area inside the controlled area that would include the process buildings and the UBC Storage Pad (LES, 2004c). To evaluate whether accidents would exceed the environmental performance requirement, the 24-hour average uranium concentration is calculated at the restricted area boundary. It is assumed that the points of release are the stacks on the roof of the Technical Services Building.

The total source term for the first phase of the event (before the release is stopped) is S_1. The residual source term from the time that the release is stopped, T_1, until the source is either depleted, or until 24 hours has elapsed, is S_2.

$$S_1 = \int_0^{T_1} S_1(t)dt = \int_0^{T_1} C_1(t)dt \times Q_v \times f_v = R\left[T_1 - \frac{V'}{Q_v f_v}\left\{1 - e^{-\frac{Q_v f_v T_1}{V'}}\right\}\right], \quad for\ 0 < t \le T_1$$

Eqs. C-6, C-7

$$S_2 = \int_{T_1}^{T_2} S_2(t)dt = \int_{T_1}^{T_2} C_2(t)dt \times Q_v \times f_v = R\left[1 - e^{-\frac{Q_v f_v T_1}{V'}}\right]\left[\frac{V'}{Q_v f_v}\left\{1 - e^{-\frac{Q_v f_v (T_2 - T_1)}{V'}}\right\}\right], \quad for\ T_1 < t \le T_2$$

To compare downwind concentrations with the applicable performance requirement, the uranium concentration downwind is calculated as a 24-hour average. For the restricted area boundary and the controlled area boundary, the atmospheric dispersion factor (**P**/S) for various distances from the proposed NEF process buildings to the boundary in each downwind sector is calculated using ARCON96 (NRC, 1997). The distance to the restricted area boundary and controlled area boundary in each compass sector, the persistence of the wind in each direction, and **P**/S values calculated using ARCON96 are presented in Table C-14. The highest **P**/S at the restricted area boundary, which would result in the highest downwind concentration, occurs directly east of the Technical Services Building. Therefore, the concentration at the restricted area boundary is calculated for wind blowing to the east.

The downwind concentration at the restricted area boundary is calculated for the downwind sector with the highest atmospheric dispersion factor ($\mathbf{P}/S|_{RAB}$) using Equation C-8.

$$U, \frac{mg}{m^3}\bigg|_{RAB} = \frac{\left[\int_0^{T_1} S_1(t)dt + \int_{T_1}^{T_2=24hr} S_2(t)dt\right]}{\int_0^{T_2=24hr} dt}, \frac{g}{s} \times \frac{X}{S}\bigg|_{RAB}, \frac{s}{m^3} \times 10^3 \frac{mg}{g} \times 0.68 \frac{mg\,U}{mg\,UF_6} \qquad \text{Eq. C-8}$$

Table C-14 Accident Values of Atmospheric Dispersion Factors for the Proposed NEF Boundaries

Direction from Facility	Distance from Proposed NEF		Frequency of Wind (percent)	RAB P/S (s/m^3)	CAB P/S (s/m^3)
	RAB meters (feet)	CAB meters (feet)			
S	160 (524)	417 (1,368)	5.66	2.64×10^{-4}	4.84×10^{-5}
SSW	168 (552)	417 (1,368)	3.98	2.40×10^{-4}	4.80×10^{-5}
SW	210 (690)	422 (1,384)	4.91	1.69×10^{-4}	5.37×10^{-5}
WSW	261 (856)	503 (1,650)	4.87	1.14×10^{-4}	4.08×10^{-5}
W	261 (856)	769 (2,522)	6.29	1.14×10^{-4}	2.37×10^{-5}
WNW	278 (911)	1,071 (3,513)	5.52	9.96×10^{-5}	1.46×10^{-5}
NW	757 (2,484)	1,072 (3,516)	7.52	2.12×10^{-5}	1.34×10^{-5}
NNW	639 (2,098)	995 (3,264)	10.80	2.35×10^{-5}	1.13×10^{-5}
N	589 (1,932)	995 (3,264)	20.40	2.67×10^{-5}	1.18×10^{-5}
NNE	530 (1739)	754 (2473)	7.35	3.08×10^{-5}	1.77×10^{-5}
NE	463 (1,518)	581 (1,906)	5.46	3.78×10^{-5}	2.61×10^{-5}
ENE	362 (1,187)	540 (1,771)	4.68	4.96×10^{-5}	2.61×10^{-5}
E	109 (359)	540 (1,771)	4.45	4.49×10^{-4}	2.68×10^{-5}
ESE	101 (331)	540 (1,771)	2.42	4.26×10^{-4}	2.54×10^{-5}
SE	143 (469)	487 (1,597)	2.69	2.76×10^{-4}	3.10×10^{-5}
SSE	185 (607)	417 (1,368)	3.04	1.70×10^{-4}	3.95×10^{-5}

RAB - restricted area boundary.
CAB - controlled area boundary.
s/m^3 - seconds per cubic meter.
To convert seconds per cubic meter (s/m^3) to seconds per cubic foot (s/ft^3), multiply by 0.028.

Controlled Area Boundary Uranium Intake and Hydrogen Fluoride Exposure

The accident consequences to an individual at the controlled area boundary include the risks of toxicological effects of uranium intake, radiation dose from uranium intake, and exposure to hydrogen fluoride concentration in air. The uranium concentration at the controlled area boundary is calculated for the downwind sector with the highest atmospheric dispersion factor ($\mathbf{P}/S|_{CAB}$). The highest $\mathbf{P}/S$ at the controlled area boundary, which would result in the highest downwind concentration, occurs southwest of the Technical Services Building. Therefore, the accident consequences at the controlled area boundary are calculated for wind blowing to the southwest.

The 30-minute average uranium concentration at the CAB is calculated using Equation C-9.

$$[U],30\,\text{min} = \frac{\left[\int_0^{T_1} S_1(t)dt + \int_{T_1}^{T_2=24hr} S_2(t)dt\right], g}{1{,}800\,s}, \frac{g}{s} \times \left.\frac{\text{X}}{S}\right|_{CAB}, \frac{s}{m^3} \times 10^3 \frac{mg}{g} \times 0.68 \frac{mg\,U}{mg\,UF_6} \qquad \text{Eq. C-9}$$

Similarly, the unmitigated 30-minute average HF concentration is:

$$[HF],30\,\text{min} = \frac{\left[\int_0^{T_1} S_1(t)dt + \int_{T_1}^{T_2=24hr} S_2(t)dt\right], g}{1{,}800\,s}, \frac{g}{s} \times \left.\frac{\text{X}}{S}\right|_{CAB}, \frac{s}{m^3} \times 10^3 \frac{mg}{g}\, x0.23 \frac{mg\,HF}{mg\,UF_6} \qquad \text{Eq. C-10}$$

C.4.1.5 Consequence Assessment Methodology for Chronic Health Effects

Earlier studies have indicated that if fatality from suffocation caused by edema (swelling) in the lungs does not occur, the swelling resulting from hydrogen fluoride exposure will subside and recovery should be complete. Thus, acute sublethal inhalation of hydrogen fluoride is not expected to have long-term effects (NRC, 1991). Therefore, the post-accident chronic health effects evaluated are limited to the toxicological and radiological health effects to members of the public offsite resulting from exposure to uranium compounds.

Human toxicological effects of exposure to soluble uranium compounds have also been previously reviewed by the NRC (NRC, 1991). It was concluded that a single acute intake of 10 milligrams of soluble uranium would produce in humans either minimal or nondetectable effects, either short-term or long-term. Therefore, if an accident could not result in acute intakes above 10 milligrams of soluble uranium in any individual at or just beyond the site (controlled area) boundary, then no long-term health effects would be expected among the exposed population further downwind. At the proposed NEF, only one type of event is capable of causing toxicological effects among the offsite public from exposure to soluble uranium—the rupture of a large UF_6 cylinder from inadvertent overheating or overfilling. The protective measures proposed by LES to prevent this type of event are described in section 4.2.13.2 of chapter 4 of this EIS.

GENII v. 1.485 (Napier et al., 1988) is used to estimate collective radiation doses (person-rem) to members of the public resulting from post-accident inhalation and ingestion of soluble uranium compounds. The same exposure pathways, ingestion parameters, and demographic information used for section 4.2.12 of chapter 4 of this EIS are applied to estimate radiological doses to the public from accidents. The pathway assessment is provided in section C.2. The meteorological data are taken from the nearby Midland-Odessa National Weather Station.

For dose calculations to the public, it is assumed that individuals downwind spend 100 percent of the time inside the passing plume (i.e., not sheltered). For releases of uranium compounds, the north sector would have the highest collective doses because Hobbs, New Mexico, is a large population center in the prevailing downwind direction.

C.4.2 Accident Analyses

C.4.2.1 Inadvertent Nuclear Criticality

An inadvertent nuclear criticality at the proposed NEF would result from the unintended accumulation of enriched uranium, leading ultimately to a self-sustaining or runaway nuclear chain reaction. A criticality accident could release large amounts of heat and radiation. A criticality accident could also produce radioactive fission products, such as isotopes of noble gases like xenon and krypton, radioiodine, and radiocesium. At the proposed NEF, one process area for which this accident is postulated is the Decontamination Workshop.

Specifically, the accumulation of uranium in the citric acid tank could cause a criticality accident. For this to occur, the operator would have to fail to control the uranium mass in the tank. A criticality in the solution in the tank could produce an initial burst of 1.0×10^{18} fissions, followed by 47 bursts of 1.92×10^{17} fissions per burst, for a total of about 1×10^{19} fissions in 8 hours (NRC, 1998b).

The source term (ST) for the inadvertent nuclear criticality was determined using the five-factor formula:

$$ST = MAR \times DR \times ARF \times RF \times LPF \qquad \text{Eq. C-11}$$

where MAR = material at risk
DR = damage ratio
ARF = airborne release fraction
RF = respirable fraction
LPF = leak path factor

For the criticality accident, the material at risk (MAR) is the amount of fission product radioactivity that would accumulate during the event (NRC, 1998b). The damage ratio (DR) is 1, since all of the solution in the tank would be involved in the event. The atmospheric release fraction (ARF) for noble gases is 100 percent. The ARF for radioiodine is 0.25, and the ARF for other fission products is 5×10^{-4} (NRC, 1998b). The respirable fraction is assumed to be 100 percent. A leak path factor (LPF) of 0.001 is used for radioiodine and fission products other than noble gases, since the Technical Services Building gaseous effluent vent system is equipped with high efficiency particulate air and charcoal filters (LES, 2005a).

The results of the consequence assessment are presented in Table C-15. Industry experience with this type of criticality accident indicates that a worker located in the immediate vicinity of the reaction is not likely to survive the accident. However, with increasing distance from the accident, the radiation doses would be lower, and the probability that a worker could survive increases. At the proposed NEF, workers would have direct access to vessels and other process equipment in which criticality events would be possible. Therefore, the accident has been qualitatively evaluated as a high consequence event for the worker.

The environmental consequence is evaluated using the sum-of-the-fractions rule. The concentration at the restricted area boundary of each fission product radionuclide generated during a hypothetical uranium solution criticality event (NRC, 1998b) is compared to 5,000 times the corresponding values in Appendix B to 10 CFR Part 20. The fractions thus generated (i.e., calculated fission product concentrations divided by their Appendix B limits) are added to yield one value. If that value is less than 1, the accident consequences to the environment are low. Since the sum presented in Table C-14 is less than 1, the postulated criticality event is estimated to be a low consequence to the environment.

Table C-15 Health Effects Resulting from Inadvertent Nuclear Criticality

Worker (egress after 10 min.)	Environment at RAB (Ratio)	Individual at CAB, SW Direction	Collective Dose, West Direction	
			person-rem	LCFs
High	0.66[a]	0.14 rem[b] (.0014 Sv)	44	0.03

[a] Pursuant to 10 CFR § 70.61(c)(3), this value is the sum of the fractions of individual fission product radionuclide concentrations over 5,000 times the concentration limits that appear in 10 CFR Part 20, Appendix B, Table 2.
[b] The dose to the individual at the controlled area boundary is the sum of internal and external doses from fission products released from the Technical Service Buildings Gaseous Effluent Vent System stack.
RAB - restricted area boundary.
CAB - controlled area boundary.
LCF - latent cancer fatalities.
Sv - sievert.
To convert rem to sievert, multiply by 0.01.

A maximally exposed individual at the controlled area boundary in the southwest direction would receive a TEDE of 0.14 rem (0.0014 sievert). This is a low consequence to this individual. Similarly, the low collective dose to the offsite population in the west sector (Eunice) means that the risk of health effects to the offsite public (latent cancer) from this accident is low. The west sector would have the highest radiation doses following a criticality accident, because the city of Eunice, New Mexico, lies in closer proximity to the proposed NEF than other population centers. Also, short-lived radionuclides formed during the criticality accident would not have completely decayed before reaching Eunice. Larger population centers in the north sector, such as the city of Hobbs, New Mexico, would receive lower collective doses because the short-lived fission products would decay during the time the plume travels from the proposed NEF.

In accordance with the performance requirements of 10 CFR Part 70, Subpart H, LES has either identified Items Relied on for Safety to reduce the risk to the proposed NEF worker from all criticality accidents or identified safe-by-design components that meet criteria such that they are high unlikely to fail.

C.4.2.2 Hydraulic Rupture of a UF_6 Cylinder in the Blending and Liquid Sampling Area

At the Product Blending System in the Blending and Liquid Sampling Area of the Separations Building, Type 30B (2.5-ton [2.3-metric ton]) cylinders would be filled with product to customer specifications. The transfer of product to Type 30B cylinders would begin by heating a 14-ton (13-metric ton) Type 48Y cylinder containing product UF_6 inside a Blending Donor Station to no more than 61°C (142 °F). The heated UF_6 gas would be transferred by piping from the heated Type 48Y cylinder to a Blending Receiver Station containing a Type 30B cylinder. The Blending Receiver Station would be cooled, which would allow the UF_6 gas to desublime to a solid inside the Type 30B cylinder, completing the transfer.

An accident is postulated wherein the Blending Donor Station heater controller fails, causing the blending donor heater within the station to remain on. Were this to occur, the product cylinder could overheat and the cylinder could hydraulically rupture due to the expansion of the liquid UF_6. Upon cylinder rupture, the entire contents of the Type 48Y product cylinder (12,501 kilograms [27,560 pounds] of UF_6) would be released within the Blending Donor Station. Since the station enclosure is not airtight, the UF_6 would be released to the Blending and Liquid Sampling Area. The UF_6, when in contact with air, would produce hydrogen fluoride gas and UO_2F_2. The release into the building would then be released to the environment. The heating, ventilation, and air-conditioning is conservatively assumed to be operating at the maximum ventilation flow rate. Significant quantities of hydrogen fluoride and UO_2F_2 would be carried by the prevailing wind beyond the controlled area boundary.

The results of the consequence assessment are presented in Table C-16 and show the health and environmental consequences of this accident would be high.

Table C-16 Health Effects Resulting from Hydraulic Rupture of a UF_6 Cylinder

Worker (egress after 10 minutes)		**Environment at RAB**	**Individual at CAB, SW Direction**		**Collective Dose, North Direction**	
U mg/m^3 (rem)	HF mg/m^3	U mg/m^3	U mg/m^3 (rem)	HF mg/m^3	person-rem	LCFs
High		44	250 (0.97)	86	12,000	7

RAB - restricted area boundary.
CAB -controlled area boundary.
HF - hydrogen fluoride.
LCF - latent cancer fatalities.
U - uranium.
mg - milligram.
m^3 - cubic meters.
To convert rem to sievert, multiply by 0.01.

The health and environmental consequences of this accident are high. A worker in the vicinity of the Blending Donor Station would be exposed within seconds to lethal UF_6, UO_2F_2, and hydrogen fluoride concentrations. The environmental consequences are higher than the 5.4 milligrams uranium per cubic meter threshold for an intermediate consequence. An individual located on the controlled area boundary in the southwest sector would suffer high consequences from both uranium and hydrogen fluoride exposure. The collective dose to the offsite population in the north sector indicates a risk of several latent cancer fatalities in the population in the years following the accident.

In accordance with the performance requirements of 10 CFR Part 70, Subpart H, LES has identified Items Relied on for Safety to reduce the risk to the proposed NEF workers, the public, and the environment from the effects of this accident. To prevent this accident, LES would rely on fail-safe, hard-wired, high-temperature heater trips and redundant, independent, fail-safe, capillary high temperature heater trips. Each control would be tested annually to ensure its availability and reliability to serve its intended safety function on demand. The purpose of these controls would be to ensure that the accident is highly unlikely to occur. In addition, there have been no similar heater control failures at the Urenco facilities in Europe in over 30 years of operation.

In addition to Items Relied on for Safety, LES has committed to an Emergency Plan that includes certain mitigating actions to reduce the consequences of the event. For example, in response to an alarm that indicates the release of UF_6, a control-room operator could secure the heating, ventilation, and air conditioning systems for the affected area. The action to secure the heating, ventilation, and air-conditioning within minutes of the accident would considerably reduce the risk to the public and the environment.

C.4.2.3 Natural Phenomena Hazard—Earthquake

An earthquake is postulated to breach all UF_6 piping systems and lead to a release of approximately 860 kilograms (1,896 pounds) of UF_6 (LES, 2005a). The value used for the peak horizontal and vertical accelerations is 0.15g. The rationale for selecting the design-basis earthquake is found in LES's ISA Summary. The staff evaluated this accident for the Blending and Liquid Sampling Area, UF_6 Handling Areas, and the Cascade Halls. LES has committed to ensure the affected process buildings can withstand the design-basis earthquake. Therefore, for this evaluation, the staff assumed that the buildings would remain intact. LES would also install and maintain an electrical trip system for select heating, ventilation, and air-conditioning systems in process areas with large inventories of gaseous UF_6. The trip system would detect earthquakes and secure the heating, ventilation, and air-conditioning units. Therefore, for this evaluation, it is also assumed that the heating, ventilation, and air-conditioning in affected process buildings would be shut down.

The results of the consequence assessment are presented in Table C-17 for a worker located in one of the Cascade Halls during the earthquake. Depending on the location of the worker when the event occurs, the large quantity of UF_6 which could be released would result in a high consequence to this individual before he or she could escape the room. However, for seismic events, the worker is assumed to evacuate the area of concern upon detection of a seismic event, which results in a reduced exposure time and an acceptable risk. The consequences to the environment would be low. The maximally exposed individual at the controlled area boundary in the southwest direction would not be expected to suffer any observable health effects. Similarly, the low collective dose to the offsite population in the north sector means that the risk of health effects to the offsite public (latent cancer) from this accident would be low.

Table C-17 Health Effects Resulting from an Earthquake

Worker (egress after 10 minutes)		Environment at RAB	Individual at CAB, SW Direction		Collective Dose, North Direction	
U mg/m3 (rem)	HF mg/m3	U mg/m^3	U mg/m3 (rem)	HF mg/m3	person-rem	LCFs
Low		0.11	0.64 (0.0017)	0.22	14	0.008

RAB - restricted area boundary.
CAB - controlled area boundary.
HF - hydrogen fluoride.
LCF - latent cancer fatalities.
U - uranium.
mg - milligram.
m^3 - cubic meter.
To convert rem to sievert, multiply by 0.01.

C.4.2.4 Fire in a UF_6 Handling Area

A fire involving transient combustible material is postulated to breach a UF_6 transfer manifold containing feed vapor from five feed stations in a single UF_6 Handling Area. The release would involve approximately 3.4 kilograms (7.5 pounds) of UF_6 vapor.

The results of the consequence assessment are presented in Table C-18. The consequences of this accident are low for the environment, the individual at the CAB, and the public offsite. For the facility worker, the consequences are intermediate for acute chemical exposure to uranium. However, for fires, the worker is assumed to evacuate the area of concern once the fire is detected, which would result in an exposure time much shorter than 10 minutes, thus resulting in acceptable risk.

Table C-18 Health Effects Resulting from Fire in a UF_6 Handling Area

Worker (egress after 10 minutes)		Environment at RAB	Individual at CAB, SW Direction		Collective Dose, North Direction	
U mg/m^3 (rem)	HF mg/m^3	U mg/m^3	U mg/m^3 (rem)	HF mg/m^3	person-rem	LCFs
59 (0.020 rem)	20	0.012	0.070 (0.000072)	0.024	0.92	0.0006

RAB - restricted area boundary.
CAB - controlled area boundary.
HF - hydrogen fluoride.
LCF - latent cancer fatalities.
U - uranium.
mg - milligram.
m^3 - cubic meter.
To convert rem to sievert, multiply by 0.01.

In accordance with the performance requirements of 10 CFR Part 70, Subpart H, LES has identified Items Relied on for Safety to ensure the risk of this type of accident remains low. To reduce the magnitude of fires resulting from the presence of transient combustible material, LES would rely on administrative controls. The purpose of these controls is to prevent large fires that could result in the release of large inventories of UF_6.

C.4.2.5 Process Line Rupture in a Product Low-Temperature Takeoff Station

Cold traps and chemical traps would be used at the proposed NEF to remove residual UF_6 and hydrogen fluoride from process lines prior to discharging exhaust gases from these lines to the gaseous effluent vent system. An accident could occur if a product vent subsystem carbon trap became saturated with UF_6 caused by a small UF_6 leak through a product cold trap valve. Were this to occur, a UF_6 plug could form on the discharge of the vacuum pump, causing high pressure in the vacuum pump and thus failing seals leading to a release of approximately 1.0 kilogram (2 pounds) of UF_6 vapor to the UF_6 Handling Area.

The results of the consequence assessment are presented in Table C-19 and show that the consequences of this accident are low for the proposed NEF worker, the environment, the individual at the controlled area boundary, and the public offsite.

Table C-19 Acute Health Effects Resulting from Process Line Rupture in a Product Low-Temperature Takeoff Station

Worker (egress after 10 minutes)		Environment at RAB	Individual at CAB, SW Direction		Collective Dose, NNW Direction	
U mg/m^3 (rem)	HF mg/m^3	U mg/m^3	U mg/m^3 (rem)	HF mg/m^3	person-rem	LCFs
17 (0.022 rem)	5.8	0.0035	0.020 (0.000078 rem)	0.0069	0.97	0.0006

RAB - restricted area boundary.
CAB - controlled area boundary.
HF - hydrogen fluoride.
LCF - latent cancer fatalities.
U - uranium.
mg - milligram.
m^3 - cubic meter.
To convert rem to sievert, multiply by 0.01.

In accordance with the performance requirements of 10 CFR Part 70, Subpart H, LES has identified Items Relied on for Safety to ensure the risk of this type of accident remains low. For this accident, a preventive measure is a fail-safe, hard-wired, high-carbon trap weight trip of the vacuum pump. This equipment would be tested annually to ensure its availability and reliability to serve its intended safety function.

C.4.3 Consequence Assessment for Land and Biota Effects

The hydraulic rupture of a UF_6 cylinder is used to demonstrate the potential impacts that an accident at the proposed NEF would have on the surrounding land and biota. This accident releases the maximum quantity of UF_6 and thus bounds the impacts of all of the accidents described in this appendix.

As described in section C.4.2, the postulated rupture could release up to 12,500 kilograms (27,600 pounds) of UF_6 into the Blending Donor Station and then to the Sampling Area. The release into the building would then be released into the atmosphere. The consequences of such a release on the surrounding land and biota are considered by analogy with the consequences from a similar accident that occurred at the Sequoyah Fuels Corporation in January 1986 (NRC, 1986). A rupture of a cylinder containing 13,380 kilograms (29,500 pounds) of UF_6 was caused by a supervisor taking actions contrary to operating procedures. The rupture resulted in the release of UF_6 outside of the building. The release formed a cloud consisting of the chemical products of UF_6 reacting with the moisture in the air to create UO_2F_2 and hydrogen fluoride. It was estimated that 75 percent of the release occurred over 5 minutes with the remaining 25 percent of the release occurring over the subsequent 40 minutes. The plume was transported along with the wind which was blowing at 8 meters per second (18 miles per hour) with atmospheric stability class D.

Areas over which the release products from this accident at Sequoyah Fuels Corporation were deposited were estimated in NUREG-1189 (NRC, 1986). Uranium deposition of 13,600 milligrams per square meter (0.045 ounces per square foot) was found onsite while an area of 7.68 square kilometers (2.97 square miles) was found to encompass uranium depositions of 1.36 milligrams per square meter (4.5×10^{-6} ounces per square foot). Soil concentration action levels of 40 micrograms per gram for uranium and 350 micrograms per gram for fluoride were established based on health considerations.

Deposition rates were converted to soil concentration by assuming that the deposited material mixes with the upper centimeter (inch) of soil having a typical density of 2 grams per cubic centimeter (about 125 pounds per cubic foot). Uranium soil concentrations were then found to exceed the action level within an area of approximately 0.32 square kilometers (0.20 square miles). This area extended approximately 1 kilometer (0.6 miles) from the release location. The fluoride soil concentration action level was found to not extend offsite.

Cattle located onsite were examined by veterinarians and showed no ill effects from the release. Their urine samples did indicate elevated levels of fluoride and uranium. Animals on farms beyond Sequoyah Fuels Corporation were considered free to move to slaughter in the normal manner. The highest levels of uranium and fluoride were contained onsite. The effects on vegetation of the lower levels found offsite were expected to be insignificant.

These effects at Sequoyah Fuels Corporation are expected to be somewhat greater than the effects that would result if a similar (bounding) accident were to occur at the proposed NEF. The quantity of UF_6 subject to release at the proposed NEF would be approximately 93 percent of that at Sequoyah Fuels Corporation. The release rates from the proposed NEF would be less than those at Sequoyah Fuels Corporation because the former release would be from building ventilation rather than directly outside. At the proposed NEF, somewhat less than half of the released material would enter the environment outside of the building in the first 30 minutes after the rupture. This lower release rate to the environment would result in lower environmental concentrations in the site vicinity. Winds at the proposed NEF could be expected to result in at least as much dispersion as the winds at Sequoyah Fuels Corporation did during the accident. The wind speed at the proposed NEF would be greater than 7 meters per second (15.7 miles per hour) 72.2 percent of the time (see section 3.5.2.4, Winds and Atmospheric Stability, of this EIS); the atmospheric stability would be class D or less stable 65.8 percent of the time. Lesser wind speeds or more stable atmospheric conditions would result in less dispersion and elevated soil concentrations extending further, although not spreading as much laterally.

C.4.4 Accident Analysis Summary

A representative subset of the potential accidents that could occur at the proposed NEF was selected and evaluated with the summary of the five potential accidents given in Table C-20. The accident consequences vary in magnitude and include accidents initiated by natural phenomena, operator error, and equipment failure. Analytical results indicate that accidents at the proposed NEF pose acceptably low risks. The most significant accident consequences are those associated with the release of UF_6 caused by rupturing an overfilled and/or overheated cylinder. The proposed NEF design would reduce the risk (likelihood) of this event by using redundant heater controller trips. In addition, the proposed NEF Emergency Plan addresses this type of event and all other lower-risk, high-consequence, and intermediate-consequence events. The NRC staff concludes that through the combination of plant design, passive and active engineered controls (Items Relied on for Safety), and administrative controls, accidents at the proposed NEF would pose an acceptably low risk to workers, the environment, and the public.

Table C-20 Summary of Health Effects Resulting from Accidents at the Proposed NEF

Accident	Worker[a] U mg/m³ (rem)	Worker[a] HF mg/m³	Environment at RAB U mg/m³	Individual at CAB, SW Direction U mg/m³ (rem)	Individual at CAB, SW Direction HF mg/m³	Collective Dose Direction	Collective Dose person-rem	Collective Dose LCFs
Inadvertent Nuclear Criticality	High[b]		0.66[c]	(0.14[d])	---	West	44	0.03
Hydraulic Rupture of a UF_6 Cylinder	High[b]		44	250 (0.97)	86	North	12,000	7[e]
Earthquake	Low		0.11	0.64 (0.0017)	0.13	North	19	0.008
Fire in a UF_6 Handling Area	59 (0.020)	20	0.012	0.070 (0.000072)	0.024	North	0.92	0.0006
Process Line Rupture	17 (0.022)	5.8	0.0035	0.020 (0.000078)	0.0069	North	0.97	0.0006

[a] Worker exits after 10 minutes.
[b] High consequence could lead to a fatality.
[c] Pursuant to 10 CFR § 70.61(c)(3), this value is the sum of the fractions of individual fission product radionuclide concentrations over 5,000 times the concentration limits that appear in 10 CFR Part 20, Appendix B, Table 2.
[d] The dose to the individual at the controlled area boundary is the sum of internal and external doses from fission products released from the Technical Services Buildings Gaseous Effluent Vent System stack.
[e] Though the consequences of the rupture of a liquid-filled UF_6 cylinder would be high, redundant heater controller trips would make this event highly unlikely.
RAB - restricted area boundary.
CAB - controlled area boundary.
HF - hydrogen fluoride.
LCF - latent cancer fatalities.
U - uranium.
mg - milligram.
m^3 - cubic meter.
To convert rem to sievert, multiply by 0.01.

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APPENDIX D
TRANSPORTATION METHODOLOGY, ASSUMPTION, AND IMPACTS

D.1 Introduction

This appendix presents the methodology, assumptions, and results for the transportation of radioactive materials to and from the proposed National Enrichment Facility (NEF). Also included is the transportation of the converted triuranium octaoxide (U_3O_8) and calcium fluoride (CaF_2) (if necessary) resulting from the conversion of the depleted uranium hexafluoride (DUF_6). The CaF_2 is generated during the conversion process from the neutralization of hydrofluoric acid. However, if the conversion process is performed at a potential facility at Metropolis, Illinois, the hydrofluoric acid would be reused at that facility. Louisiana Energy Services (LES) has proposed to use only trucks for the transport of radioactive shipments; however, this appendix also assumes that rail transport would be a viable option.

Briefly, the impact assessment determines the following: the origin and destination of each type of radioactive material, the amount of material in each shipment, the mode of shipment (truck or rail), the route to be used, and impacts to the environment from these shipments. In this process, the WebTragis and RADTRAN 5 computer codes were used extensively and are discussed in more detail later (ORNL, 2003; Neuhauser and Kanipe, 2003). The appendix is organized into separate sections that describe the radioactive materials, the shipping routes, the dose assessments, and the results.

D.2 Radioactive Material Description

The radioactive materials transported to and from the proposed NEF are subject to both U.S. Nuclear Regulatory Commission (NRC) (10 Code of Federal Regulations [CFR] Part 71) and U.S. Department of Transportation (49 CFR Parts 171-173) shipping regulations. All shipments of UF_6 can be transported in Type A shipping containers that also have thermal protection (e.g., overpack or other protective assembly) that meet the requirements of 49 CFR § 173.420 and 10 CFR § 71.73(c)(4). Shipments of the product material are required to have fissile controls in addition to the thermal protection. However, in this assessment of the radiological impacts, any reduction in exposures due to the presence of a thermal and/or fissile overpack is ignored.

Several different types of radioactive materials are proposed for shipment. Table D-1 presents the composition of four different types of containers proposed for the shipment of feed, product, depleted uranium, and waste. Figures D-1 through D-3 are diagrams and Tables D-2 through D-4 are the specifications for the Type 30B, 48X, and 48Y cylinders, respectively. One year of decay was included as a conservative assumption to account for a delay in shipping between the generation of the natural UF_6 and any radioactive shipments.

Three other radioactive materials requiring transportation that result from the conversion of DUF_6 are depleted U_3O_8, CaF_2, and empty Type 48Y cylinders. Assuming no change in isotopic concentration of the four uranium isotopes, the U_3O_8 material would have the same curie content as the DUF_6. The CaF_2 could have about 55 becquerels (1.5 picocuries) per gram of depleted uranium as a radioactive contaminate (DOE, 2004a; DOE 2004b). The empty Type 48Y cylinders would contain residues, or heels, that would remain after evacuation of the UF_6. For this analysis, NRC staff assumes the empty Type 48Y cylinders would be shipped from the proposed NEF and the adjacent private conversion facility to the feed material suppliers using the same routes for shipping feed material to the proposed NEF. Based on a 11,340-kilogram (25,000-pound) amount of processed material, Table D-5 presents the curie inventory of the converted U_3O_8 and CaF_2. This amount of material presents the approximate net load that a truck could reasonably haul without obtaining special permits.

The radionuclide data and shipping container characteristics for input into RADTRAN 5 were obtained from the U.S. Department of Energy's (DOE's) *A Resource Handbook on DOE Transportation Risk Assessment* (DOE, 2002) and the NRC's NUREG-0170 (NRC, 1977).

Table D-1 Curie Inventory in Selected Shipping Containers for Truck Transportation[a]

Radionuclide	Feed Material (Natural Uranium as UF_6)		Product (Enriched Uranium as UF_6)	Depleted Uranium (DUF_6)	Residue (Heels)	Solid Waste
	Type 48Y Cylinder	Type 48X Cylinder	Type 30B Cylinder	Type 48Y Cylinder	Type 48Y Cylinder	55-Gallon Drum
Tl-207	4.28×10^{-8}	3.29×10^{-8}	5.74×10^{-8}	2.05×10^{-8}	1.39×10^{-8}	6.84×10^{-12}
Tl-208	1.75×10^{-15}	1.35×10^{-15}	2.35×10^{-15}	8.35×10^{-16}	1.25×10^{-15}	2.80×10^{-19}
Pb-210	5.52×10^{-11}	4.25×10^{-11}	8.71×10^{-11}	2.48×10^{-11}	4.49×10^{-11}	8.82×10^{-15}
Pb-211	4.29×10^{-8}	3.30×10^{-8}	5.75×10^{-8}	2.05×10^{-8}	1.39×10^{-8}	6.86×10^{-12}
Pb-212	4.87×10^{-15}	3.75×10^{-15}	6.53×10^{-15}	2.32×10^{-15}	3.47×10^{-15}	7.79×10^{-19}
Pb-214	5.45×10^{-9}	4.20×10^{-9}	8.61×10^{-9}	2.45×10^{-9}	1.91×10^{-9}	8.72×10^{-13}
Bi-210	5.52×10^{-11}	4.25×10^{-11}	8.71×10^{-11}	2.48×10^{-11}	4.38×10^{-11}	8.82×10^{-15}
Bi-211	4.29×10^{-8}	3.30×10^{-8}	5.75×10^{-8}	2.05×10^{-8}	1.39×10^{-8}	6.86×10^{-12}
Bi-212	4.87×10^{-15}	3.75×10^{-15}	6.53×10^{-15}	2.32×10^{-15}	3.47×10^{-15}	7.79×10^{-19}
Bi-214	5.45×10^{-9}	4.20×10^{-9}	8.61×10^{-9}	2.45×10^{-9}	1.91×10^{-9}	8.72×10^{-13}
Po-210	1.79×10^{-11}	1.38×10^{-11}	2.82×10^{-11}	8.04×10^{-12}	2.32×10^{-11}	2.86×10^{-15}
Po-211	1.20×10^{-10}	9.25×10^{-11}	1.61×10^{-10}	5.75×10^{-11}	3.90×10^{-11}	1.92×10^{-14}
Po-212	3.12×10^{-15}	2.40×10^{-15}	4.18×10^{-15}	1.49×10^{-15}	2.22×10^{-15}	4.99×10^{-19}
Po-214	5.45×10^{-9}	4.20×10^{-9}	8.60×10^{-9}	2.45×10^{-9}	1.91×10^{-9}	8.71×10^{-13}
Po-215	4.29×10^{-8}	3.30×10^{-8}	5.75×10^{-8}	2.05×10^{-8}	1.39×10^{-8}	6.86×10^{-12}
Po-216	4.87×10^{-15}	3.75×10^{-15}	6.53×10^{-15}	2.32×10^{-15}	3.47×10^{-15}	7.79×10^{-19}
Po-218	5.45×10^{-9}	4.20×10^{-9}	8.61×10^{-9}	2.45×10^{-9}	1.91×10^{-9}	8.72×10^{-13}
Rn-219	4.29×10^{-8}	3.30×10^{-8}	5.75×10^{-8}	2.05×10^{-8}	1.39×10^{-8}	6.86×10^{-12}
Rn-220	4.87×10^{-15}	3.75×10^{-15}	6.53×10^{-15}	2.32×10^{-15}	3.47×10^{-15}	7.79×10^{-19}
Rn-222	5.45×10^{-9}	4.20×10^{-9}	8.61×10^{-9}	2.45×10^{-9}	1.91×10^{-9}	8.72×10^{-13}
Fr-223	5.92×10^{-10}	4.56×10^{-10}	7.94×10^{-10}	2.83×10^{-10}	2.09×10^{-10}	9.47×10^{-14}
Ra-223	4.29×10^{-8}	3.30×10^{-8}	5.75×10^{-8}	2.05×10^{-8}	1.39×10^{-8}	6.86×10^{-12}
Ra-224	4.87×10^{-15}	3.75×10^{-15}	6.53×10^{-15}	2.32×10^{-15}	3.47×10^{-15}	7.79×10^{-19}
Ra-226	5.45×10^{-9}	4.20×10^{-9}	8.61×10^{-9}	2.45×10^{-9}	1.93×10^{-9}	8.72×10^{-13}
Ra-228	4.37×10^{-14}	3.37×10^{-14}	5.86×10^{-14}	2.09×10^{-14}	1.48×10^{-14}	6.99×10^{-18}
Ac-227	4.29×10^{-8}	3.30×10^{-8}	5.75×10^{-8}	2.05×10^{-8}	1.51×10^{-8}	6.86×10^{-12}

Radionuclide	Feed Material (Natural Uranium as UF_6)		Product (Enriched Uranium as UF_6)	Depleted Uranium (DUF_6)	Residue (Heels)	Solid Waste
	Type 48Y Cylinder	Type 48X Cylinder	Type 30B Cylinder	Type 48Y Cylinder	Type 48Y Cylinder	55-Gallon Drum
Ac-228	4.37×10^{-14}	3.37×10^{-14}	5.86×10^{-14}	2.09×10^{-14}	1.48×10^{-14}	6.99×10^{-18}
Th-227	4.23×10^{-8}	3.26×10^{-8}	5.67×10^{-8}	2.02×10^{-8}	1.42×10^{-8}	6.77×10^{-12}
Th-228	4.87×10^{-15}	3.75×10^{-15}	6.53×10^{-15}	2.32×10^{-15}	3.53×10^{-15}	7.79×10^{-19}
Th-230	2.52×10^{-5}	1.94×10^{-5}	3.97×10^{-5}	1.13×10^{-5}	3.01×10^{-6}	4.03×10^{-9}
Th-231	1.29×10^{-1}	9.91×10^{-2}	1.73×10^{-1}	6.16×10^{-2}	0	2.06×10^{-5}
Th-232	8.74×10^{-13}	6.73×10^{-13}	1.17×10^{-12}	4.17×10^{-13}	1.04×10^{-13}	1.40×10^{-16}
Th-234	2.8	2.15	5.10×10^{-1}	2.81	1.06×10^{-5}	4.47×10^{-4}
Pa-231	2.72×10^{-6}	2.10×10^{-6}	3.65×10^{-6}	1.30×10^{-6}	3.28×10^{-7}	4.36×10^{-10}
Pa-234m	2.8	2.15	5.10×10^{-1}	2.81	1.06×10^{-5}	4.47×10^{-4}
Pa-234	3.64×10^{-3}	2.80×10^{-3}	6.63×10^{-4}	3.65×10^{-3}	1.38×10^{-8}	5.82×10^{-7}
U-234	2.8	2.15	4.42	1.26	9.01×10^{-8}	4.47×10^{-4}
U-235	1.29×10^{-1}	9.91×10^{-2}	1.73×10^{-1}	6.16×10^{-2}	0	2.06×10^{-5}
U-236	1.77×10^{-2}	1.36×10^{-2}	2.38×10^{-2}	8.46×10^{-3}	0	2.83×10^{-6}
U-238	2.8	2.15	5.10×10^{-1}	2.81	0	4.47×10^{-4}

[a] Includes 1-year decay and in-growth.
To convert from curies to becquerels multiply by 3.7×10^{10}.
Source: LES, 2004.

Table D-2 Type 30B Cylinder Specifications

Parameter	Value
Nominal Diameter	76 centimeters (30 inches)
Nominal Length	206 centimeters (81 inches)
Wall Thickness	1.27 centimeters (0.5 inch)
Nominal Tare Weight	635 kilograms (1,400 pounds)
Maximum Net Weight	2,300 kilograms (5,000 pounds)
Nominal Gross Weight	2,900 kilograms (6,400 pounds)
Minimum Volume	736 liters (26 cubic feet)
Basic Material of Construction	Steel: ASTM A-516
Service Pressure	1,380 kiloPascals gage (200 pounds per square inch gage)
Hydrostatic Test Pressure	2,760 kiloPascals gage (400 pounds per square inch gage)
Isotopic Content Limit	5.0 percent uranium-235 (^{235}U) (maximum with moderation control)
Valve Used	2.54-centimeter valve (1-inch valve)

Source: USEC, 1995.

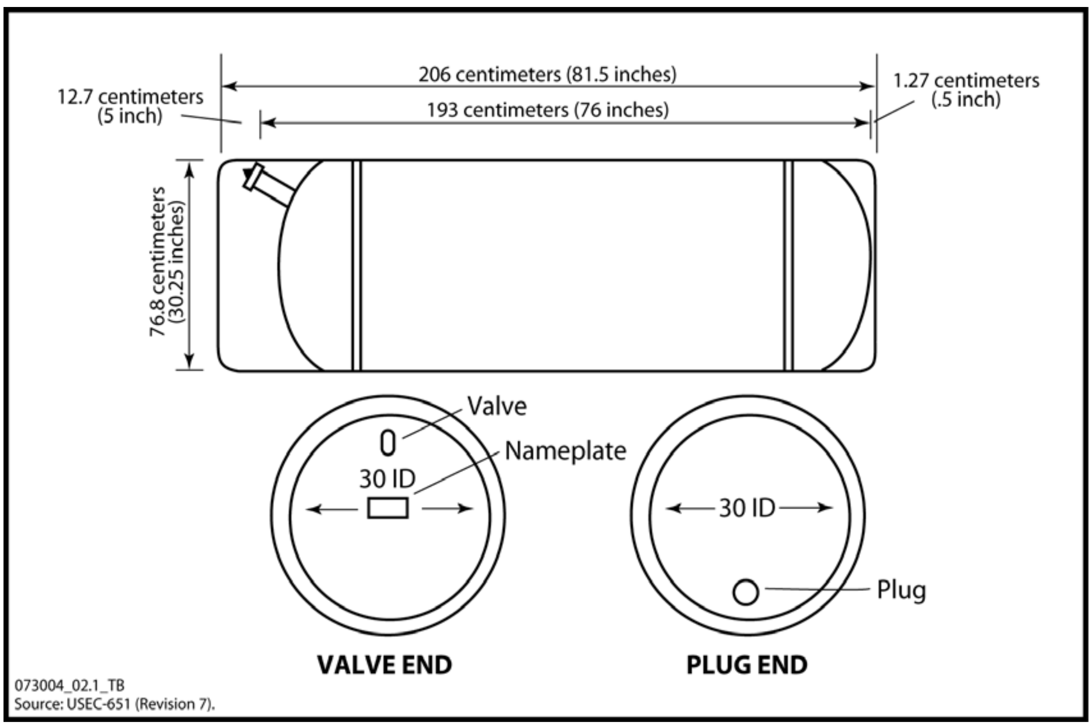

Figure D-1 Schematic of a Type 30B Cylinder (USEC, 1995)

Table D-3 Type 48X Cylinder Specifications

Parameter	Value
Nominal Diameter	122 centimeters (48 inches)
Nominal Length	302 centimeters (119 inches)
Wall Thickness	1.6 centimeters (0.625 inch)
Nominal Tare Weight	2,000 kilograms (4,500 pounds)
Maximum Net Weight	9,540 kilograms (21,000 pounds)
Nominal Gross Weight	11,600 kilograms (25,500 pounds)
Minimum Volume	3.048 cubic meters (108.9 cubic feet)
Basic Material of Construction	Steel: ASTM A-516
Service Pressure	1,380 kiloPascals gage (200 pounds per square inch gage)
Hydrostatic Test Pressure	2,760 kiloPascals gage (400 pounds per square inch gage)
Isotopic Content Limit	4.5 percent ^{235}U (maximum with moderation control for transport, 5.0% for in-plant use)
Valve Used	2.54-centimeter valve (1-inch valve)

Source: USEC, 1995.

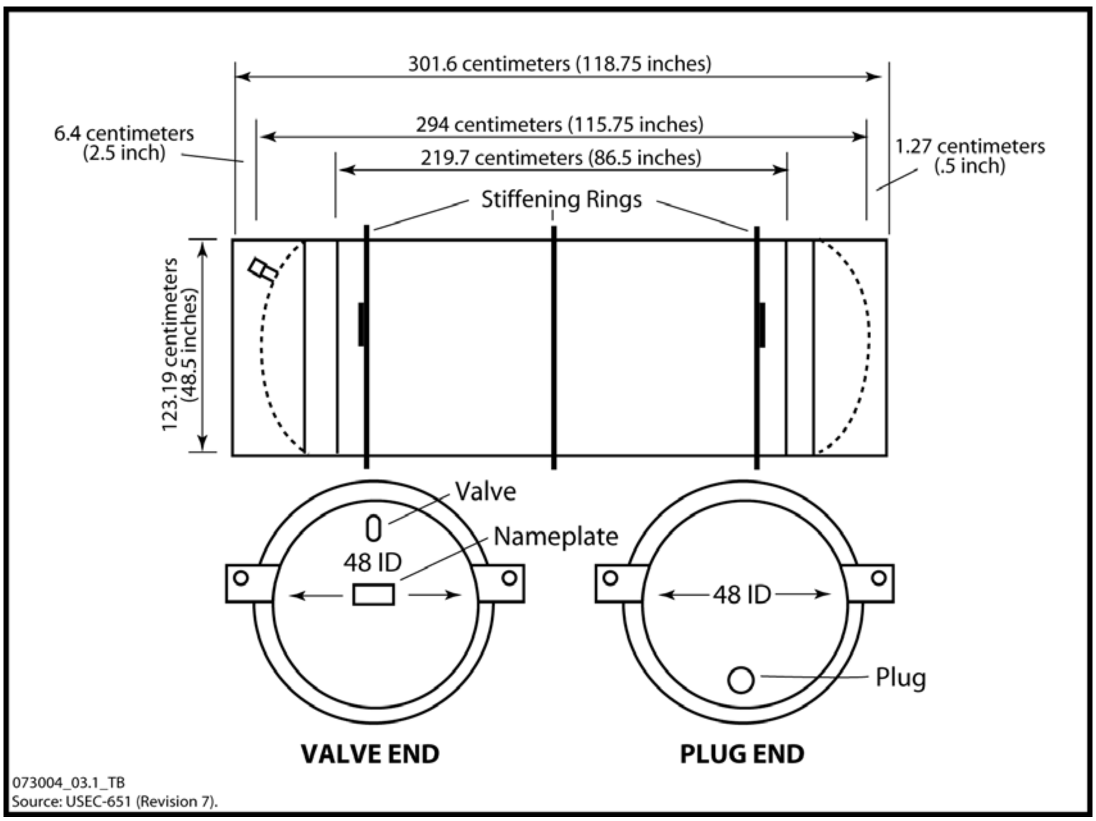

Figure D-2 Schematic of a Type 48X Cylinder (USEC, 1995)

Table D-4 Type 48Y Cylinder Specifications

Parameter	Value
Nominal Diameter	122 centimeters (48 inches)
Nominal Length	380 centimeters (150 inches)
Wall Thickness	1.6 centimeters (0.625 inches)
Nominal Tare Weight	2,359 kilograms (5,200 pounds)
Maximum Net Weight	12,500 kilograms (27,560 pounds)
Nominal Gross Weight	14,860 kilograms (32,760 pounds)
Minimum Volume	4.04 cubic meters (142.7 cubic feet)
Basic Material of Construction	Steel: ASTM A-516
Service Pressure	1,380 kiloPascals gage (200 pounds per square inch gage)
Hydrostatic Test Pressure	2,760 kiloPascals gage (400 pounds per square inch gage)
Isotopic Content Limit	4.5 percent ^{235}U (maximum with moderation control)
Valve Used	2.54-centimeter valve (1-inch valve)

Source: USEC, 1995.

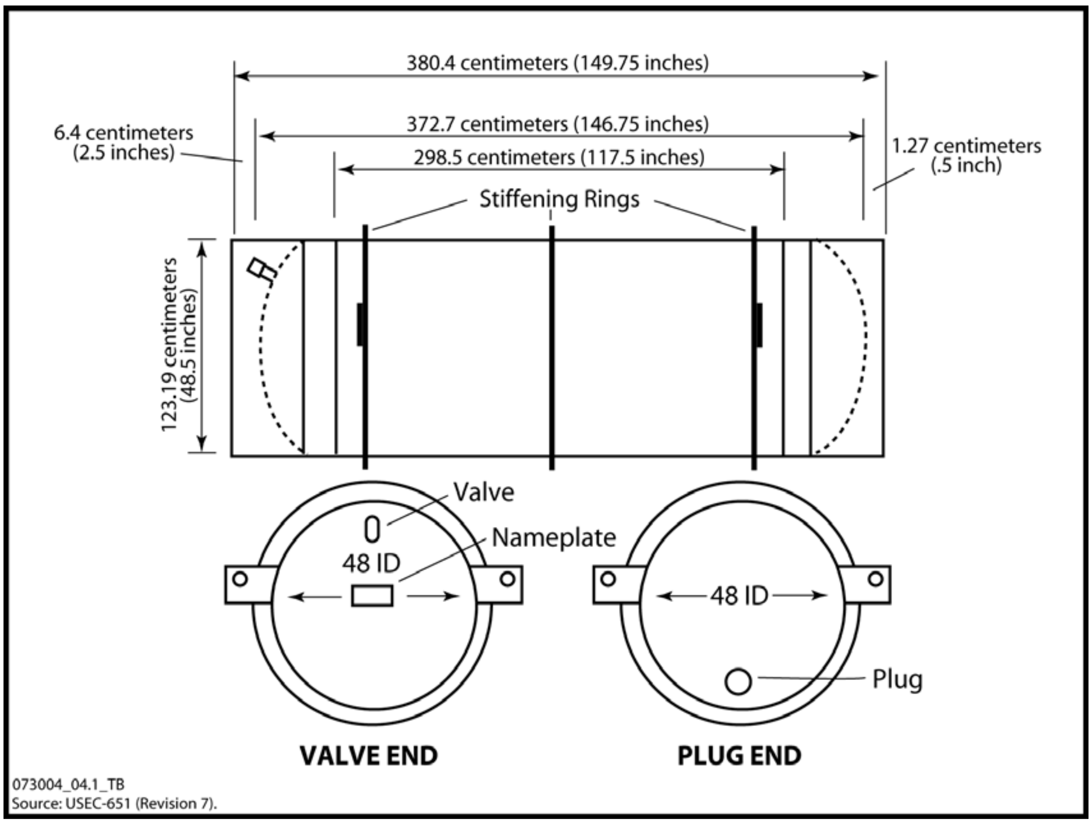

Figure D-3 Schematic of a Type 48Y Cylinder (USEC, 1995)

Table D-5 Curie Content of U_3O_8 and CaF_2 Based on 11,340-Kilogram (25,000-Pound) Amounts

	Curie Content	
Radionuclide	**U_3O_8 [a, b]**	**CaF_2 [a, c]**
Uranium-234	4.47	1.70×10^{-5}
Uranium-235	0.218	5.82×10^{-9}
Uranium-236	0.03	1.72×10^{-7}
Uranium-238	9.94	9.05×10^{-10}

[a] Based on the DUF_6 radionuclide concentration.
[b] Based on a material conversion of 1.18 pounds of U_3O_8 per pound of uranium in UF_6.
[c] Based on the material conversion of 2.05 pound of CaF_2 per pound of F in UF_6 and 1.5 picocurie contamination of depleted uranium per gram of CaF_2.
To convert from curies to becquerels, multiply by 3.7×10^{10}.

The NRC staff reviewed the number of shipments and the number of packages per truck based on the amount of materials being shipped to or from the proposed NEF. The NRC staff assumed that the contents of a railcar have the equivalent content of four trucks. Table D-6 presents the number of packages and number of trucks or railcars that would be required for the transport.

Table D-6 Number of Packages and Number of Trucks or Railcars Required for the Transport

Material	Type of Container	Number of		
		Containers	**Trucks**	**Railcars**
Natural UF_6	Type 48X[a]	890[a]	890[a]	223
	Type 48Y[a]	690[a]	690[a]	173
Enriched UF_6	Type 30B[a]	350[a]	117[a]	30
DUF_6	Type 48Y[a]	627[a]	627[a]	157
Depleted U_3O_8	11,340-kg (25,000-lb) bulk bags[b]	547	547	137
CaF_2	11,340-kg (25,000-lb) bulk bags[b]	461	461	116
Solid Waste	55 gallon drums[a]	480[a]	8[a]	2
Empty Cylindersc	Type 48Y[a]	690	345	87

kg - kilogram.; lb - pound.
[c]Shipment of empty Type 48Y cylinders would be from the proposed NEF (63 empty cylinders per year) and the adjacent private conversion facility (627 empty cylinders per year).
Sources: [a] LES, 2005; [b] DOE, 2004a;DOE, 2004b.

Table D-7 provides a summary of information regarding estimates of the direct radiation near each type of shipping container (LES, 2004).

Note that in Table D-7, the external radiation levels for an empty cylinder are higher than those for a full cylinder. This occurs for two reasons. First, after UF_6 is vaporized and removed from a cylinder, the radioactive uranium daughter products that build up due to the radioactive decay of uranium collect at the bottom and form what is known as a “heel.” The nature of the radiation emitted from the uranium daughter products results in a greater release of gamma radiation than occurs from just uranium. Second, uranium is also a good shield material for gamma radiation. When the cylinder is full of UF_6, the uranium daughters are distributed throughout the cylinder and emitted radiation must pass through a significant amount of uranium (thus can be stopped or absorbed by the uranium). It is only gamma radiation from the uranium daughters near to the inner surface of the cylinder that can penetrate the cylinder and contribute to a nearby person's radiation exposure. Because the empty cylinder no longer has the high shielding capability of the UF_6 versus the remaining vapor, and the heel concentrates the more highly radioactive uranium daughters right next to the inner cylinder surface, the radiation levels of the empty UF_6 cylinder are higher than those for a full UF_6 cylinder.

Table D-7 Direct Radiation Surrounding Shipping Containers

Item	Feed Material in Type 48X Cylinder	Feed Material in Type 48Y Cylinder	Product in Type 30B Cylinder	DUF_6 in Type 48Y Cylinder	Solid Waste in 55-gallon drum	Empty Type 48Y Cylinder
Direct Radiation at 1 meter (mrem/hr)	0.26	0.29	0.19	0.28	0.0042	1.0
Direct Radiation at 2 meters (mrem/hr)	0.0722	0.0722	0.032	0.072	0.0013	0.26 (estimated)

mrem/hr - millirems per hour.
To convert from millirems to millisieverts, multiply by 1×10^{-2}.
Source: LES, 2004; LES, 2005.

The direct radiation from the DUF_6 cylinder was assumed to be representative of the direct radiation from the shipments of U_3O_8 and CaF_2 via truck. The U_3O_8 and CaF_2 were assumed to be shipped in bulk bags on a truck in 11,340-kilogram (25,000-pound) amounts. For shipments by railroad, a railcar could transport four times the amount that is proposed to be transported by truck. The direct radiation per cylinder was assumed to remain the same.

In addition to the radioactive materials released from containers of UF_6 (either natural, enriched, or depleted) during an accident, toxic chemicals could be released, as discussed in section D.5. The impacts are also discussed in section D.5.

D.3 Transportation Routes

This section presents the various shipping routes for the radioactive material to and from the sites and from the U_3O_8 conversion facility. WebTragis (ORNL, 2003) was used to generate the routing information for both the truck and railroad routes. WebTragis is a web-based version of Tragis (Transport Routing Analysis Geographic Information System) and is used to calculate highway, rail, or waterway routes within the United States. These routes are considered representative of the routes that would be used. Table D-8 presents a matrix of the shipping origins and destinations for the various radioactive materials.

For this Environmental Impact Statement (EIS), both truck and rail shipments were assumed to be valid modes of transport for each route. For some routes, the destination is not directly served by rail and it is assumed that the radioactive materials would be transferred to truck for delivery to the final destination. WebTragis generates routing distance, population density within 800 meters (0.5 mile), and for the truck routes, the number of rest stops and stops for State inspections. Tables D-9 and D-10 present the output from WebTragis to be used in the transportation assessment for truck and rail transport, respectively. For Port Hope, Ontario, an additional 241 kilometers (150 miles) of route distance and an inspection stop was added to the WebTragis output to account for that portion of the route located in Canada. Even though transportation regulations by truck do not require restricted routing for the shipment of natural uranium, low-enriched uranium, or depleted uranium, routing restrictions were applied as follows:

- Highway Route Controlled Quantity preferred route with two drivers.
- Prohibit use of links prohibiting truck use.
- Prohibit use of ferry crossing; prohibit use of roads with hazardous materials prohibition.
- Prohibit use of roads with radioactive materials prohibition.

Table D-8 Shipping Origins and Destinations

Route	Feed Material (Natural UF_6)	Product (Enriched UF_6)	DUF_6	Depleted U_3O_8	CaF_2	Solid Waste	Empty Type 48Y Cylinder
Port Hope, ON, to NEF [a]	X						
Metropolis, IL, to NEF [a]	X						
NEF to Columbia, SC [a]		X					
NEF to Wilmington, NC [a]		X					
NEF to Richland, WA [a]		X					
NEF to Paducah, KY			X				
NEF to Portsmouth, OH			X				
NEF to Metropolis, IL [a]			X				
NEF to Clive, UT [a]				X[b]	X[b]	X	
NEF to Hanford, WA [a]				X[b]	X[b]	X	
NEF to Barnwell, SC [a]						X	
NEF to Oak Ridge, TN [a]						X	
Metropolis, IL, to Clive, UT				X			
Paducah, KY, to Clive, UT				X			
Portsmouth, OH, to Clive, UT				X			
Paducah, KY, to NTS, NV				X			
Portsmouth, OH, to NTS, NV				X			
Adjacent Conversion Facility to Port Hope, ON [a]							X
Adjacent Conversion Facility to Metropolis, IL [a]							X

[a] LES, 2005.

ON - Ontario, Canada. NEF - proposed NEF. IL - Illinois. SC - South Carolina.
NC - North Carolina. WA - Washington. KY - Kentucky. OH - Ohio.
UT - Utah. TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.

[b] As discussed in section 2.1.9, Option 1b, it was assumed that the conversion facility could be located within 6.4 kilometers (4.0 miles) of the proposed NEF.

Table D-9 Distance, Density, and Stop Information Generated by WebTragis for Truck Routes

Facility	Number of Stops		Link Type	Distance Per Trip (km [mile])		Population Density (people/km^2 [mile^2])	
	Inspection	Rest					
UF_6 Conversion Facility, Port Hope, Ontario, Canada	7	9	Rural	2,026.6	(1,259.3)	15.5	(40.6)
			Suburban	1,053.0	(654.3)	333.1	(872.0)
			Urban	129.9	(80.7)	2,276.8	(5,960.2)
UF_6 Conversion Facility, Metropolis, IL	3	4	Rural	1,329.1	(825.9)	12.6	(33.0)
			Suburban	414.8	(257.7)	320.9	(840.1)
			Urban	44.0	(27.3)	2,255.3	(5,903.9)
Fuel Fabrication Facility, Columbia, SC	5	6	Rural	1,557.8	(968.0)	24.5	(64.1)
			Suburban	689.5	(428.4)	318.2	(833.0)
			Urban	65.8	(40.9)	2,193.6	(5,742.4)
Fuel Fabrication Facility, Wilmington, NC	6	7	Rural	1,850.5	(1,149.8)	14.8	(38.7)
			Suburban	836.3	(519.7)	309.1	(809.2)
			Urban	69.4	(43.1)	2,191.9	(5,738.0)
Fuel Fabrication Facility, Richland, WA	7	9	Rural	2,950.9	(1,833.6)	7.6	(19.9)
			Suburban	501.8	(311.8)	342.3	(896.1)
			Urban	85.2	(52.9)	2,318.5	(6,069.4)
Barnwell, SC	5	6	Rural	1,549.8	(963.0)	14.1	(36.9)
			Suburban	644.2	(400.3)	321.6	(841.9)
			Urban	65.8	(40.9)	2,170.6	(5,682.2)
Hanford, WA	7	9	Rural	2,986.4	(1,855.7)	7.6	(19.9)
			Suburban	501.2	(311.4)	342.5	(896.6)
			Urban	85.0	(52.8)	2,316.6	(6,064.4)
Clive, UT	4	7	Rural	2,265.7	(1,407.8)	6.8	(17.8)
			Suburban	369.3	(229.5)	375.2	(982.2)
			Urban	84.5	(52.5)	2,359.3	(6,176.2)
Oak Ridge, TN	2	5	Rural	1,432.9	(890.4)	13.6	(35.6)
			Suburban	512.2	(318.3)	336.0	(879.6)
			Urban	69.7	(43.3)	2,264.6	(5,928.3)
DUF_6 Conversion Facility, Paducah, KY	4	5	Rural	1,348.0	(837.6)	12.6	(33.0)
			Suburban	418.4	(260.0)	319.2	(835.6)
			Urban	42.8	(26.6)	2,269.3	(5,940.6)
DUF_6 Conversion Facility, Portsmouth, OH	4	6	Rural	1,660.0	(1,031.5)	14.9	(39.0)
			Suburban	671.1	(417.0)	326.9	(855.8)
			Urban	78.8	(49.0)	2,249.1	(5,887.7)
Depleted U_3O_8 from Metropolis, IL, to Clive, UT	8	8	Rural	2,615.2	(1,625.0)	11.3	(29.6)
			Suburban	562.3	(349.4)	315.2	(825.1)
			Urban	69.1	(42.9)	2,293.8	(6,004.7)

Facility	Number of Stops		Link Type	Distance Per Trip (km [mile])		Population Density (people/km² [mile²])	
	Inspection	Rest					
Depleted U_3O_8 from Paducah, KY, to NTS, NV	8	8	Rural	2,731.3	(1,697.2)	9.9	(25.9)
			Suburban	532.2	(330.7)	328.0	(858.6)
			Urban	85.5	(53.1)	2,377.6	(6,224.1)
Depleted U_3O_8 from Portsmouth, OH, to NTS, NV	10	9	Rural	3,106.3	(1,930.2)	10.9	(28.5)
			Suburban	659.2	(409.6)	319.9	(837.4)
			Urban	99.4	(61.8)	2,396.6	(6,273.8)
Depleted U_3O_8 from Paducah, KY, to Clive, UT	6	7	Rural	2,240.2	(1,392.0)	10.1	(26.4)
			Suburban	435.3	(270.5)	323.8	(847.6)
			Urban	55.1	(34.2)	2,238.4	(5,859.7)
Depleted U_3O_8 from Portsmouth, OH, to Clive, UT	8	8	Rural	2,615.2	(1,625.0)	11.3	(29.6)
			Suburban	562.3	(349.4)	315.2	(825.1)
			Urban	69.1	(42.9)	2,293.8	(6,004.7)

ON - Ontario, Canada. IL - Illinois. SC - South Carolina. NC - North Carolina.
WA - Washington. KY - Kentucky. OH - Ohio. UT - Utah.
TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.
Source: Calculations using WebTragis (ORNL, 2003).

Table D-10 Distance, Density Information Generated by WebTragis for Rail Routes

Facility	Link Type	Distance Per Trip (km [mi])		Population Density (people/km² [mile²])	
UF_6 Conversion Facility Port Hope, Ontario, Canada	Rural	2,361.0	(1,467.1)	11.3	(29.6)
	Suburban	769.3	(478.0)	436.3	(1,142.1)
	Urban	164.2	(102.0)	2,358.8	(6,174.9)
UF_6 Conversion Facility, Metropolis, IL	Rural	1,637.6	(1,017.6)	9.7	(25.4)
	Suburban	411.0	(255.4)	427.6	(1,119.4)
	Urban	56.4	(35.0)	2,148.4	(5,624.1)
Fuel Fabrication Facility, Columbia, SC	Rural	1,919.5	(1,192.7)	11.8	(30.9)
	Suburban	801.5	(498.0)	427.1	(1,118.1)
	Urban	122.1	(75.9)	2,169.1	(5,678.3)
Fuel Fabrication Facility, Wilmington, NC	Rural	2,150.7	(1,336.4)	12.0	(31.4)
	Suburban	878.0	(545.6)	424.0	(1,109.9)
	Urban	125.3	(77.9)	2,162.2	(5,660.2)
Fuel Fabrication Facility, Richland, WA	Rural	3,027.6	(1,881.3)	6.8	(17.8)
	Suburban	550.1	(341.8)	379.3	(992.9)
	Urban	168.2	(104.5)	2,567.5	(6,721.2)
Barnwell, SC	Rural	1,937.1	(1,203.7)	11.6	(30.4)
	Suburban	728.8	(452.9)	436.2	(1,141.9)
	Urban	129.5	(80.5)	2,210.2	(5,785.9)

Facility	Link Type	Distance Per Trip (km [mi])		Population Density (people/km^2 [mile^2])	
Hanford, WA	Rural	3,035.5	(1,886.2)	6.8	(17.8)
	Suburban	554.1	(344.3)	380.5	(996.1)
	Urban	171.0	(106.3)	2,560.2	(6,702.1)
Clive, UT	Rural	2,668.2	(1,657.9)	5.4	(14.1)
	Suburban	327.1	(203.3)	362.9	(950.0)
	Urban	82.2	(51.1)	2,496.7	(6,535.9)
Oak Ridge, TN	Rural	1,734.2	(1,077.6)	11.4	(29.8)
	Suburban	634.6	(394.3)	429.6	(1,124.6)
	Urban	97.5	(60.6)	2,158.5	(5,650.5)
DUF_6 Conversion Facility, Paducah, KY	Rural	1,441.2	(895.5)	10.2	(26.7)
	Suburban	425.4	(264.3)	440.0	(1,151.8)
	Urban	65.4	(40.6)	2,174.9	(5,693.5)
DUF_6 Conversion Facility, Portsmouth, OH	Rural	1,944.0	(1,207.9)	12.2	(31.9)
	Suburban	643.0	(399.5)	423.2	(1,107.9)
	Urban	117.7	(73.1)	2,269.2	(5,940.3)
Depleted U_3O_8 from Metropolis, IL, to Clive, UT	Rural	2,489.1	(1,546.7)	7.1	(18.6)
	Suburban	343.2	(213.3)	363.9	(952.6)
	Urban	54.2	(33.7)	2,309.7	(6,046.3)
Depleted U_3O_8 from Paducah, KY, to NTS, NV	Rural	2,935.8	(1,842.2)	6.3	(6.3)
	Suburban	360.2	(223.8)	430.7	(435.3)
	Urban	76.3	(47.4)	2,196.4	(2,219.9)
Depleted U_3O_8 from Portsmouth, OH, to NTS, NV	Rural	3,191.9	(1,983.4)	7.8	(7.9)
	Suburban	494.3	(307.1)	365.1	(369.1)
	Urban	141.4	(87.9)	2,597.9	(2,625.9)
Depleted U_3O_8 from Paducah, KY, to Clive, UT	Rural	2,513.3	(1,561.7)	7.2	(7.3)
	Suburban	360.5	(224.0)	371.3	(375.4)
	Urban	56.3	(35.0)	2,293.0	(2,317.5)
Depleted U_3O_8 from Portsmouth, OH, to Clive, UT	Rural	2,669.1	(1,658.5)	8.4	(8.4)
	Suburban	503.0	(312.5)	392.1	(396.3)
	Urban	126.8	(78.8)	2,374.7	(2,400.3)

ON - Ontario, Canada. IL - Illinois. SC - South Carolina. NC - North Carolina.
WA - Washington. KY - Kentucky. OH - Ohio. UT - Utah.
TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.
km - kilometer; km^2 - square kilometer.
Source: Calculations using WebTragis (ORNL, 2003).

D.4 RADTRAN 5

The RADTRAN 5 computer code was used to estimate the impacts of the radioactive material shipments (Neuhauser and Kanipe, 2003). The potential impacts include health effects from the exposure to pollution from trucks or railroads, fatalities from truck or rail accidents, health effects from incident-free direct radiation to crew and surrounding populations along the transportation routes, and health effects from the release of radioactive material in transportation accidents. In addition to the WebTragis information, additional input parameters for RADTRAN 5 are required as discussed below.

D.4.1 Accident Parameters

The amount of radioactive material released from a transportation accident depends on the packaging of the material and the severity of the accident. A method widely used to characterize the potential severity of transportation accidents is described in NUREG-0170 (NRC, 1977) and is also presented in DOE's *A Resource Handbook on DOE Transportation Risk Assessment* (DOE, 2002). The NRC method divided the spectrum of accident severities into eight categories with each category being subdivided into rural, suburban, and urban zones containing the fraction of occurrence of the severity class within each zone. Table D-11 presents the fractional occurrences for accidents.

Table D-11 Fractional Occurrences for Accidents by Severity Category and Population Density Zone

Accident Severity Category	Fractional Occurrences of Severity Category	Fractional Occurrence by Population Zone		
		Low (Rural)	Medium (Suburban)	High (Urban)
Truck				
I	0.55	0.1	0.1	0.8
II	0.36	0.1	0.1	0.8
III	0.07	0.3	0.4	0.3
IV	0.016	0.3	0.4	0.3
V	0.0028	0.5	0.3	0.2
VI	0.0011	0.7	0.2	0.1
VII	8.50×10^{-5}	0.8	0.1	0.1
VIII	1.50×10^{-5}	0.9	0.05	0.05
Rail				
I	0.5	0.1	0.1	0.8
II	0.3	0.1	0.1	0.8
III	0.18	0.3	0.4	0.3
IV	0.018	0.3	0.4	0.3
V	0.0018	0.5	0.3	0.2
VI	1.30×10^{-4}	0.7	0.2	0.1
VII	6.00×10^{-5}	0.8	0.1	0.1
VIII	1.00×10^{-5}	0.9	0.05	0.05

Source: DOE, 2002.

Once the frequencies of the accidents are generated, the fractions controlling the amount that is airborne and respirable are required. These fractions are composed of three additional fractions: the package-release fraction, the fraction of material released that becomes airborne, and the fraction that is airborne which is respirable. These fractions were extracted from the DOE handbook (DOE, 2002). The Type A package fractions are given in Table D-12. These values are conservative because of the lack of data on package failure under severe conditions (DOE, 2002).

Table D-12 Fraction of Package Released, Aerosolized, and Respirable

Accident Severity	Release	Respirable	Aerosolized
	Truck		
I	0	1	1
II	0.01	1	1
III	0.1	1	1
IV	1	1	1
V	1	1	1
VI	1	1	1
VII	1	1	1
VIII	1	1	1
	Rail		
I	0	1	1
II	0.01	1	1
III	0.1	1	1
IV	1	1	1
V	1	1	1
VI	1	1	1
VII	1	1	1
VIII	1	1	1

[a] Assumed very conservative assumption of volatile solid.

Source: DOE, 2002, Tables 6.24 and 6.25.

To evaluate incident-free impacts, other input parameters that affect the exposure duration to the public and crew are required. Table D-13 presents the speed of the vehicle, size of crew, amount of time the package is stopped for driver rest, State inspections, population on adjacent traffic lanes or rail tracks, and other input parameters. The RADTRAN 5 input parameters not described in this appendix were set to the default values in RADTRAN 5.

Table D-13 RADTRAN 5 Input Parameters

Item	Link Type	Truck Transport	Rail Transport
Traffic Volume (vehicle)	Rural	2,400	1
	Suburban	760	1
	Urban	530	1
Vehicle Speed (mph)	Rural	55	40
	Suburban	25	25
	Urban	15	15
Number of People in Adjacent Vehicle		2	4
Size of Crew		2	5
Number of People Exposed at Rest Stop		25	N/A
Exposure Distance at Rest Stop (meters)		20	N/A
Vehicle Emission Rate (fatalities/km per 1 person/km^2)		8.36×10^{-10}	1.2×10^{-10}
Vehicle Accident		1.42×10^{-8} (fatalities/kilometer)	7.82×10^{-8} (fatalities/ railcar-kilometer)

mph - miles per hour; km - kilometer; km^2 - square kilometer.
To convert from mph to km per hour, multiply by 1.61.
To convert from meters to feet, multiply by 3.28.
To convert from miles to kilometers, multiply by 1.61.
N/A - not applicable.
Source: DOE, 2002.

D.4.2 RADTRAN 5 Results

This section provides the detailed results of the RADTRAN 5 analyses. Tables D-14 through D-16 present the results by route and type of material being transported for one year by truck. Tables D-17 through D-19 present the results by route and type of material being transported for one year by rail. Tables D-14 and D-17 present the nonradiological impacts from the shipment of radioactive material. They present the estimated potential impact in terms of latent cancer fatalities from the vehicle emissions and fatalities resulting from traffic accidents. Tables D-15 and D-18 present the radiological impacts in terms of latent cancer fatalities from incident-free transport. Incident-free transport represents the transport of the radioactive shipment without a release from the shipment. Tables D-16 and D-19 present the radiological impacts from accidents during these shipments. Accident results include the impact (risk per year) from various accident scenarios that potentially could occur during the transport of the radioactive material. The results are presented in terms of risk, which means weighting the impact, of the various accident scenarios by the frequency that the accident scenario occurs.

Results are presented in terms of a range of values for each type of shipment. The range represents the impacts from the lowest to highest impact for the various proposed shipping routes. For example, for the feed/heel materials, the values represent one year of shipments from both Metropolis, Illinois, and Port Hope, Ontario, Canada and the return of the empty Type 48Y cylinders from the proposed NEF and adjacent private conversion facility. If some feed materials were provided from Metropolis and the remaining amounts from Port Hope, the impacts would be somewhere between the low and high values (impacts could be evaluated by taking the fraction of material from Metropolis times the impacts from Metropolis plus the fraction of material from Port Hope times the impacts from Port Hope).

To evaluate the impact from transportation of radioactive materials, a scenario first has to be selected. Then the impacts from the various materials and routes should be summed. For example, the proposed NEF would receive feed material from Metropolis, Illinois, in Type 48Y cylinders. The product material would be shipped from the proposed NEF to Wilmington, North Carolina. The solid waste would be shipped from the proposed NEF to Clive, Utah, while the DUF_6 would be shipped to Metropolis, Illinois. The converted U_3O_8 would then be shipped to Clive, Utah, for disposal. The impacts from all these material routes should be summed to determine the impact for this scenario. The results that are labeled as "Total Impacts" contain the results of the impacts summed over each of the four types of material. Therefore, these impacts represent the range from the low to high impacts.

For both truck and rail transport, the nonradiological impacts (fatalities from either traffic and train accidents and latent cancer fatalities) dominate the impacts for each material-route combination.

Table D-14 Nonradiological Fatalities from Truck Transportation of Radioactive Materials

Material	Route	Occupational		Nonoccupational	
		Normal (LCFs)	Accident (Fatalities)	Normal (LCFs)	Accident (Fatalities)
Feed Material in Type 48X Cylinder	Port Hope, ON	1×10^{-2}	6×10^{-2}	1	2×10^{-1}
Feed Material in Type 48Y Cylinder	Port Hope, ON	8×10^{-3}	5×10^{-2}	8×10^{-1}	2×10^{-1}
Feed Material in Type 48X Cylinder	Metropolis, IL	5×10^{-3}	4×10^{-2}	4×10^{-1}	2×10^{-1}
Feed Material in Type 48Y Cylinder	Metropolis, IL	4×10^{-3}	3×10^{-2}	3×10^{-1}	1×10^{-1}
Product in Type 30B Cylinder	Columbia, SC	9×10^{-4}	6×10^{-3}	8×10^{-2}	2×10^{-2}
Product in Type 30B Cylinder	Wilmington, NC	1×10^{-3}	7×10^{-3}	8×10^{-2}	3×10^{-2}
Product in Type 30B Cylinder	Richland, WA	1×10^{-3}	1×10^{-2}	8×10^{-2}	4×10^{-2}
DUF_6 in Type 48Y Cylinder	Paducah, KY	4×10^{-3}	3×10^{-2}	3×10^{-1}	1×10^{-1}
DUF_6 in Type 48Y Cylinder	Portsmouth, OH	5×10^{-3}	4×10^{-2}	4×10^{-1}	1×10^{-1}
DUF_6 in Type 48Y Cylinder	Metropolis, IL	4×10^{-3}	3×10^{-2}	3×10^{-1}	1×10^{-1}
Empty Type 48Y Cylinder	Metropolis, IL	2×10^{-3}	2×10^{-2}	2×10^{-1}	6×10^{-2}
Empty Type 48Y Cylinder	Port Hope, ON	4×10^{-3}	2×10^{-2}	4×10^{-1}	9×10^{-2}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to NTS, NV	6×10^{-3}	5×10^{-2}	5×10^{-2}	2×10^{-1}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to Clive, UT	5×10^{-3}	4×10^{-2}	4×10^{-2}	2×10^{-1}

Material	Route	Occupational		Nonoccupational	
		Normal (LCFs)	Accident (Fatalities)	Normal (LCFs)	Accident (Fatalities)
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH to NTS	7×10^{-3}	5×10^{-2}	6×10^{-2}	2×10^{-1}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to Clive, UT	6×10^{-3}	5×10^{-2}	5×10^{-2}	2×10^{-1}
Depleted U_3O_8 in Bulk Bags	Metropolis, IL, to Clive, UT	3×10^{-3}	2×10^{-2}	1×10^{-1}	8×10^{-2}
Depleted U_3O_8 in Bulk Bags	Clive, UT	5×10^{-3}	4×10^{-2}	3×10^{-1}	2×10^{-1}
Depleted U_3O_8 in Bulk Bags	Hanford, WA	7×10^{-3}	5×10^{-2}	4×10^{-1}	2×10^{-1}
CaF_2 in Bulk Bags	Clive, UT	4×10^{-3}	3×10^{-2}	3×10^{-1}	1×10^{-1}
CaF_2 in Bulk Bags	Hanford, WA	6×10^{-3}	4×10^{-2}	3×10^{-1}	2×10^{-1}
Solid Waste in 55-Gallon Drums	Barnwell, SC	6×10^{-5}	4×10^{-4}	5×10^{-3}	2×10^{-3}
Solid Waste in 55-Gallon Drums	Clive, UT	7×10^{-5}	6×10^{-4}	5×10^{-3}	2×10^{-3}
Solid Waste in 55-gallon drums	Hanford, WA	1×10^{-4}	8×10^{-4}	5×10^{-3}	3×10^{-3}
Solid Waste in 55-Gallon Drums	Oak Ridge, TN	6×10^{-5}	4×10^{-4}	5×10^{-3}	1×10^{-3}
Range					
Feed Material	Low	4×10^{-3}	3×10^{-2}	3×10^{-1}	1×10^{-1}
	High	1×10^{-2}	6×10^{-2}	1	2×10^{-1}
Product	Low	9×10^{-4}	6×10^{-3}	8×10^{-2}	2×10^{-2}
	High	1×10^{-3}	1×10^{-2}	8×10^{-2}	4×10^{-2}
Disposition of Depleted Uranium	Low	3×10^{-3}	2×10^{-2}	4×10^{-2}	8×10^{-2}
	High	7×10^{-3}	5×10^{-2}	4×10^{-1}	2×10^{-1}
Waste	Low	6×10^{-5}	4×10^{-4}	5×10^{-3}	1×10^{-3}
	High	1×10^{-4}	8×10^{-4}	5×10^{-3}	3×10^{-3}
Empty Cylinders	Low	2×10^{-3}	2×10^{-2}	2×10^{-1}	6×10^{-2}
	High	4×10^{-3}	2×10^{-2}	4×10^{-1}	9×10^{-2}
Total Impacts	Low	1×10^{-2}	7×10^{-2}	6×10^{-1}	3×10^{-1}
	High	2×10^{-2}	2×10^{-1}	2	6×10^{-1}

ON - Ontario, Canada. IL - Illinois. SC - South Carolina. NC - North Carolina.
WA - Washington. KY - Kentucky. OH - Ohio. UT - Utah.
TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.

Table D-15 Radiological Latent Cancer Fatalities from Incident-Free Truck Transportation of Radioactive Materials

Material	Route	Maximum Individual	Crew	In-Transit Public Off-Link	Public On-Link	Public Stop	Crew Loading	State Inspection	Total Public	Total Worker
Feed Material in Type 48X Cylinder	Port Hope, ON	7×10^{-9}	1×10^{-3}	3×10^{-4}	2×10^{-3}	2×10^{-3}	9×10^{-4}	7×10^{-3}	3×10^{-3}	9×10^{-3}
Feed Material in Type 48Y Cylinder	Port Hope, ON	5×10^{-9}	9×10^{-4}	2×10^{-4}	1×10^{-3}	1×10^{-3}	5×10^{-4}	5×10^{-3}	2×10^{-3}	6×10^{-3}
Feed Material in Type 48X Cylinder	Metropolis, IL	7×10^{-9}	6×10^{-4}	1×10^{-4}	6×10^{-4}	7×10^{-4}	9×10^{-4}	2×10^{-3}	1×10^{-3}	3×10^{-3}
Feed Material in Type 48Y Cylinder	Metropolis, IL	5×10^{-9}	4×10^{-4}	9×10^{-5}	5×10^{-4}	5×10^{-4}	5×10^{-4}	1×10^{-3}	1×10^{-3}	2×10^{-3}
Product in Type 30B Cylinder	Columbia, SC	4×10^{-10}	3×10^{-5}	1×10^{-5}	6×10^{-5}	6×10^{-5}	2×10^{-4}	6×10^{-4}	1×10^{-4}	8×10^{-4}
Product in Type 30B Cylinder	Wilmington, NC	4×10^{-10}	4×10^{-5}	1×10^{-5}	6×10^{-5}	7×10^{-5}	2×10^{-4}	7×10^{-4}	1×10^{-4}	9×10^{-4}
Product in Type 30B Cylinder	Richland, WA	4×10^{-10}	4×10^{-5}	9×10^{-6}	6×10^{-5}	9×10^{-5}	2×10^{-4}	9×10^{-4}	2×10^{-4}	1×10^{-3}
DUF_6 in Type 48Y Cylinder	Paducah, KY	5×10^{-9}	4×10^{-4}	8×10^{-5}	4×10^{-4}	6×10^{-4}	6×10^{-4}	2×10^{-3}	1×10^{-3}	3×10^{-3}
DUF_6 in Type 48Y Cylinder	Portsmouth, OH	5×10^{-9}	6×10^{-4}	1×10^{-4}	7×10^{-4}	7×10^{-4}	6×10^{-4}	2×10^{-3}	2×10^{-3}	3×10^{-3}
DUF_6 in Type 48Y Cylinder	Metropolis, IL	5×10^{-9}	4×10^{-4}	8×10^{-5}	4×10^{-4}	5×10^{-4}	6×10^{-4}	1×10^{-3}	1×10^{-3}	2×10^{-3}
Empty Type 48Y Cylinder	Metropolis, IL	9×10^{-9}	5×10^{-4}	1×10^{-4}	7×10^{-4}	8×10^{-4}	1×10^{-3}	3×10^{-3}	2×10^{-3}	5×10^{-3}
Empty Type 48Y Cylinder	Port Hope, ON	9×10^{-9}	1×10^{-3}	4×10^{-4}	2×10^{-3}	2×10^{-3}	1×10^{-3}	1×10^{-2}	4×10^{-3}	1×10^{-2}

Material	Route	Maximum Individual	Crew	In-Transit Public Off-Link	In-Transit Public On-Link	In-Transit Public Stop	Crew Loading	Crew State Inspection	Total Public	Total Worker
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to NTS, NV	4×10^{-9}	6×10^{-4}	9×10^{-5}	6×10^{-4}	8×10^{-4}	1×10^{-4}	8×10^{-4}	2×10^{-3}	2×10^{-3}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to Clive, UT	4×10^{-9}	5×10^{-4}	8×10^{-5}	5×10^{-4}	8×10^{-4}	1×10^{-4}	8×10^{-4}	1×10^{-3}	1×10^{-3}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to NTS	4×10^{-9}	7×10^{-4}	1×10^{-4}	7×10^{-4}	9×10^{-4}	1×10^{-4}	1×10^{-3}	2×10^{-3}	2×10^{-3}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to Clive, UT	4×10^{-9}	6×10^{-4}	1×10^{-4}	6×10^{-4}	9×10^{-4}	1×10^{-4}	1×10^{-3}	2×10^{-3}	2×10^{-3}
Depleted U_3O_8 in Bulk Bags	Metropolis, IL, to Clive, UT	2×10^{-9}	3×10^{-4}	4×10^{-5}	2×10^{-4}	3×10^{-4}	7×10^{-5}	3×10^{-4}	6×10^{-4}	6×10^{-4}
Depleted U_3O_8 in Bulk Bags	Clive, UT	4×10^{-9}	5×10^{-4}	7×10^{-5}	5×10^{-4}	6×10^{-4}	1×10^{-4}	4×10^{-4}	1×10^{-3}	1×10^{-3}
Depleted U_3O_8 in Bulk Bags	Hanford, WA	4×10^{-9}	6×10^{-4}	9×10^{-5}	6×10^{-4}	9×10^{-4}	1×10^{-4}	7×10^{-4}	2×10^{-3}	1×10^{-3}
CaF_2 in Bulk Bags	Clive, UT	4×10^{-9}	4×10^{-4}	6×10^{-5}	4×10^{-4}	5×10^{-4}	2×10^{-6}	6×10^{-6}	1×10^{-3}	4×10^{-4}
CaF_2 in Bulk Bags	Hanford, WA	4×10^{-9}	5×10^{-4}	8×10^{-5}	5×10^{-4}	8×10^{-4}	2×10^{-6}	1×10^{-5}	1×10^{-3}	5×10^{-4}
Solid Waste in 55-Gallon Drums	Barnwell, SC	1×10^{-12}	3×10^{-7}	3×10^{-8}	2×10^{-7}	2×10^{-7}	4×10^{-6}	1×10^{-5}	3×10^{-7}	2×10^{-5}
Solid Waste in 55-Gallon Drums	Clive, UT	1×10^{-12}	3×10^{-7}	2×10^{-8}	1×10^{-7}	2×10^{-7}	4×10^{-6}	1×10^{-5}	3×10^{-7}	1×10^{-5}
Solid Waste in 55-Gallon Drums	Hanford, WA	1×10^{-12}	4×10^{-7}	2×10^{-8}	2×10^{-7}	2×10^{-7}	4×10^{-6}	2×10^{-5}	4×10^{-7}	2×10^{-5}
Solid Waste in 55-Gallon Drums	Oak Ridge, TN	1×10^{-12}	2×10^{-7}	2×10^{-8}	1×10^{-7}	2×10^{-7}	4×10^{-6}	1×10^{-5}	3×10^{-7}	1×10^{-5}

Material	Route	Maximum Individual	Crew	In-Transit Public Off-Link	In-Transit Public On-Link	In-Transit Public Stop	Crew Loading	Crew State Inspection	Total Public	Total Worker
Range										
Feed Material	Low	5×10^{-9}	4×10^{-4}	9×10^{-5}	5×10^{-4}	5×10^{-4}	5×10^{-4}	1×10^{-3}	1×10^{-3}	2×10^{-3}
	High	7×10^{-9}	1×10^{-3}	3×10^{-4}	2×10^{-3}	2×10^{-3}	9×10^{-4}	7×10^{-3}	3×10^{-3}	9×10^{-3}
Product	Low	$4.\times10^{-10}$	3×10^{-5}	9×10^{-6}	6×10^{-5}	6×10^{-5}	2×10^{-4}	6×10^{-4}	1×10^{-4}	8×10^{-4}
	High	$4.\times10^{-10}$	4×10^{-5}	1×10^{-5}	6×10^{-5}	9×10^{-5}	2×10^{-4}	9×10^{-4}	2×10^{-4}	1×10^{-3}
Disposition of Depleted Uranium	Low	2×10^{-9}	3×10^{-4}	4×10^{-5}	2×10^{-4}	3×10^{-4}	2×10^{-6}	6×10^{-6}	6×10^{-4}	4×10^{-4}
	High	5×10^{-9}	7×10^{-4}	1×10^{-4}	7×10^{-4}	9×10^{-4}	6×10^{-4}	2×10^{-3}	2×10^{-3}	3×10^{-3}
Waste	Low	1×10^{-12}	2×10^{-7}	2×10^{-8}	1×10^{-7}	2×10^{-7}	4×10^{-6}	1×10^{-5}	3×10^{-7}	1×10^{-5}
	High	1×10^{-12}	4×10^{-7}	3×10^{-8}	2×10^{-7}	2×10^{-7}	4×10^{-6}	2×10^{-5}	4×10^{-7}	2×10^{-5}
Empty Cylinders	Low	9×10^{-9}	5×10^{-4}	1×10^{-4}	7×10^{-4}	8×10^{-4}	1×10^{-3}	3×10^{-3}	2×10^{-3}	5×10^{-3}
	High	9×10^{-9}	1×10^{-3}	4×10^{-4}	2×10^{-3}	2×10^{-3}	1×10^{-3}	1×10^{-2}	4×10^{-3}	1×10^{-2}
Total Impacts	Low	2×10^{-8}	1×10^{-3}	3×10^{-4}	1×10^{-3}	2×10^{-3}	2×10^{-3}	5×10^{-3}	3×10^{-3}	8×10^{-3}
	High	2×10^{-8}	3×10^{-3}	8×10^{-4}	4×10^{-3}	4×10^{-3}	3×10^{-3}	2×10^{-2}	9×10^{-3}	3×10^{-2}

ON - Ontario, Canada. IL - Illinois. SC - South Carolina. NC - North Carolina.
WA - Washington. KY - Kentucky. OH - Ohio. UT - Utah.
TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.

Table D-16 Risk of Latent Cancer Fatalities from Accidents During Truck Transportation of Radioactive Materials

Material	Route	Ground	Inhaled	Resuspended Soil	Cloud Shine	Total Risk of LCF
Feed Material in Type 48X Cylinder	Port Hope, ON	2×10^{-7}	2×10^{-1}	7×10^{-2}	2×10^{-11}	2×10^{-1}
Feed Material in Type 48Y Cylinder	Port Hope, ON	2×10^{-7}	2×10^{-1}	7×10^{-2}	2×10^{-11}	2×10^{-1}
Feed Material in Type 48X Cylinder	Metropolis, IL	9×10^{-8}	6×10^{-2}	3×10^{-2}	8×10^{-12}	8×10^{-2}
Feed Material in Type 48Y Cylinder	Metropolis, IL	9×10^{-8}	6×10^{-2}	2×10^{-2}	8×10^{-12}	8×10^{-2}
Product in Type 30B Cylinder	Columbia, SC	9×10^{-8}	7×10^{-2}	1×10^{-2}	3×10^{-12}	8×10^{-2}
Product in Type 30B Cylinder	Wilmington, NC	1×10^{-7}	7×10^{-2}	1×10^{-2}	3×10^{-12}	8×10^{-2}
Product in Type 30B Cylinder	Richland, WA	8×10^{-8}	6×10^{-2}	1×10^{-2}	3×10^{-12}	7×10^{-2}
DUF_6 in Type 48Y Cylinder	Paducah, KY	4×10^{-8}	3×10^{-2}	1×10^{-2}	7×10^{-12}	4×10^{-2}
DUF_6 in Type 48Y Cylinder	Portsmouth, OH	7×10^{-8}	4×10^{-2}	2×10^{-2}	1×10^{-11}	6×10^{-2}
DUF_6 in Type 48Y Cylinder	Metropolis, IL	4×10^{-8}	3×10^{-2}	1×10^{-2}	7×10^{-12}	4×10^{-2}
Empty Type 48Y Cylinder	Metropolis, IL	1×10^{-13}	6×10^{-3}	3×10^{-2}	3×10^{-17}	3×10^{-2}
Empty Type 48Y Cylinder	Port Hope, ON	3×10^{-13}	2×10^{-2}	7×10^{-2}	7×10^{-17}	9×10^{-2}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to NTS, NV	7×10^{-8}	1×10^{-4}	9×10^{-5}	1×10^{-12}	2×10^{-4}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to Clive, UT	5×10^{-8}	9×10^{-5}	6×10^{-5}	9×10^{-13}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to NTS, NV	8×10^{-8}	1×10^{-4}	1×10^{-4}	2×10^{-12}	2×10^{-4}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to Clive, UT	6×10^{-8}	1×10^{-4}	7×10^{-5}	1×10^{-12}	2×10^{-4}
Depleted U_3O_8 in Bulk Bags	Metropolis, IL, to Clive, UT	3×10^{-8}	4×10^{-5}	3×10^{-5}	5×10^{-13}	7×10^{-5}
Depleted U_3O_8 in Bulk Bags	Clive, UT	6×10^{-8}	1×10^{-4}	8×10^{-5}	1×10^{-12}	2×10^{-4}
Depleted U_3O_8 in Bulk Bags	Hanford, WA	7×10^{-8}	1×10^{-4}	8×10^{-5}	1×10^{-12}	2×10^{-4}

Material	Route	Ground	Inhaled	Resuspended Soil	Cloud Shine	Total Risk of LCF
CaF_2 in Bulk Bags	Clive, UT	5×10^{-13}	2×10^{-9}	7×10^{-9}	1×10^{-18}	9×10^{-9}
CaF_2 in Bulk Bags	Hanford, WA	5×10^{-13}	2×10^{-9}	8×10^{-9}	2×10^{-18}	1×10^{-8}
Solid Waste in 55-Gallon Drums	Barnwell, SC	2×10^{-11}	1×10^{-5}	4×10^{-5}	1×10^{-15}	5×10^{-5}
Solid Waste in 55-Gallon Drums	Clive, UT	2×10^{-11}	9×10^{-6}	3×10^{-5}	1×10^{-15}	4×10^{-5}
Solid Waste in 55-Gallon Drums	Hanford, WA	2×10^{-11}	1×10^{-5}	3×10^{-5}	1×10^{-15}	4×10^{-5}
Solid Waste in 55-Gallon Drums	Oak Ridge, TN	2×10^{-11}	9×10^{-6}	3×10^{-5}	1×10^{-15}	4×10^{-5}
		Range				
Feed Material	Low	9×10^{-8}	6×10^{-2}	2×10^{-2}	8×10^{-12}	8×10^{-2}
	High	2×10^{-7}	2×10^{-1}	7×10^{-2}	2×10^{-11}	2×10^{-1}
Product	Low	8×10^{-8}	6×10^{-2}	1×10^{-2}	3×10^{-12}	7×10^{-2}
	High	1×10^{-7}	7×10^{-2}	1×10^{-2}	3×10^{-12}	8×10^{-2}
Disposition of Depleted uranium	Low	5×10^{-13}	2×10^{-9}	7×10^{-9}	1×10^{-18}	9×10^{-9}
	High	8×10^{-8}	4×10^{-2}	2×10^{-2}	1×10^{-11}	6×10^{-2}
Waste	Low	2×10^{-11}	9×10^{-6}	3×10^{-5}	1×10^{-15}	4×10^{-5}
	High	2×10^{-11}	1×10^{-5}	4×10^{-5}	1×10^{-15}	5×10^{-5}
Empty Cylinders	Low	1×10^{-13}	6×10^{-3}	3×10^{-2}	3×10^{-17}	3×10^{-2}
	High	3×10^{-13}	2×10^{-2}	7×10^{-2}	7×10^{-17}	9×10^{-2}
Total Impact	Low	2×10^{-7}	1×10^{-1}	6×10^{-2}	1×10^{-11}	2×10^{-1}
	High	4×10^{-7}	3×10^{-1}	2×10^{-1}	4×10^{-11}	5×10^{-1}

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Table D-17 Nonradiological Fatalities from Rail Transportation of Radioactive Materials

Material	Route	Occupational		Nonoccupational	
		Normal (Latent Cancer Fatalities)	Accident (Fatalities)	Normal (LCFs)	Accident (Fatalities)
Feed Material in Type 48X Cylinder	Port Hope, ON	7×10^{-4}	1×10^{-1}	4×10^{-2}	1×10^{-1}
Feed Material in Type 48Y Cylinder	Port Hope, ON	6×10^{-4}	9×10^{-2}	3×10^{-2}	9×10^{-2}
Feed Material in Type 48X Cylinder	Metropolis, IL	5×10^{-4}	7×10^{-2}	2×10^{-2}	7×10^{-2}
Feed Material in Type 48Y Cylinder	Metropolis, IL	4×10^{-4}	6×10^{-2}	1×10^{-2}	6×10^{-2}
Product in Type 30B Cylinder	Columbia, SC	8×10^{-5}	1×10^{-2}	5×10^{-3}	1×10^{-2}
Product in Type 30B Cylinder	Wilmington, NC	9×10^{-5}	2×10^{-2}	5×10^{-3}	2×10^{-2}
Product in Type 30B Cylinder	Richland, WA	1×10^{-4}	2×10^{-2}	5×10^{-3}	2×10^{-2}
DUF_6 in Type 48Y Cylinder	Paducah, KY	3×10^{-4}	5×10^{-2}	1×10^{-2}	5×10^{-2}
DUF_6 in Type 48Y Cylinder	Portsmouth, OH	4×10^{-4}	7×10^{-2}	2×10^{-2}	7×10^{-2}
DUF_6 in Type 48Y Cylinder	Metropolis, IL	3×10^{-4}	5×10^{-2}	1×10^{-2}	5×10^{-2}
Empty Type 48Y Cylinder	Metropolis, IL	2×10^{-4}	3×10^{-2}	7×10^{-3}	3×10^{-2}
Empty Type 48Y Cylinder	Port Hope, ON	3×10^{-4}	5×10^{-2}	2×10^{-2}	5×10^{-2}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to NTS, NV	2×10^{-4}	4×10^{-2}	6×10^{-3}	4×10^{-2}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to Clive, UT	2×10^{-4}	3×10^{-2}	5×10^{-3}	3×10^{-2}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to NTS	3×10^{-4}	4×10^{-2}	1×10^{-2}	4×10^{-2}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to Clive, UT	2×10^{-4}	4×10^{-2}	9×10^{-3}	4×10^{-2}
Depleted U_3O_8 in Bulk Bags	Metropolis, IL, to Clive, UT	2×10^{-4}	3×10^{-2}	5×10^{-3}	3×10^{-2}
Depleted U_3O_8 in Bulk Bags	Clive, UT	2×10^{-4}	3×10^{-2}	6×10^{-3}	3×10^{-2}
Depleted U_3O_8 in Bulk Bags	Hanford, WA	3×10^{-4}	4×10^{-2}	1×10^{-2}	4×10^{-2}
CaF_2 in Bulk Bags	Clive, UT	4×10^{-4}	6×10^{-2}	1×10^{-2}	6×10^{-2}
CaF_2 in Bulk Bags	Hanford, WA	5×10^{-4}	8×10^{-2}	2×10^{-2}	8×10^{-2}
Solid Waste in 55-Gallon Drums	Barnwell, SC	5×10^{-6}	9×10^{-4}	3×10^{-4}	9×10^{-4}
Solid Waste in 55-Gallon Drums	Clive, UT	6×10^{-6}	9×10^{-4}	2×10^{-4}	9×10^{-4}

Material	Route	Occupational Normal (Latent Cancer Fatalities)	Occupational Accident (Fatalities)	Nonoccupational Normal (LCFs)	Nonoccupational Accident (Fatalities)
Solid Waste in 55-Gallon Drums	Hanford, WA	7×10^{-6}	1×10^{-3}	3×10^{-4}	1×10^{-3}
Solid Waste in 55-Gallon Drums	Oak Ridge, TN	5×10^{-6}	8×10^{-4}	2×10^{-4}	8×10^{-4}
Range					
Feed Material	Low	4×10^{-4}	6×10^{-2}	1×10^{-2}	6×10^{-2}
	High	7×10^{-4}	1×10^{-1}	4×10^{-2}	1×10^{-1}
Product	Low	8×10^{-5}	1×10^{-2}	5×10^{-3}	1×10^{-2}
	High	1×10^{-4}	2×10^{-2}	5×10^{-3}	2×10^{-2}
Disposition of Depleted Uranium	Low	2×10^{-4}	3×10^{-2}	5×10^{-3}	3×10^{-2}
	High	5×10^{-4}	8×10^{-2}	2×10^{-2}	8×10^{-2}
Waste	Low	5×10^{-6}	8×10^{-4}	2×10^{-4}	8×10^{-4}
	High	7×10^{-6}	1×10^{-3}	3×10^{-4}	1×10^{-3}
Empty Cylinders	Low	2×10^{-4}	3×10^{-2}	7×10^{-3}	3×10^{-2}
	High	3×10^{-4}	5×10^{-2}	2×10^{-2}	5×10^{-2}
Total Impact	Low	8×10^{-4}	1×10^{-1}	3×10^{-2}	1×10^{-1}
	High	2×10^{-3}	3×10^{-1}	8×10^{-2}	3×10^{-1}

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WA - Washington. KY - Kentucky. OH - Ohio. UT - Utah.
TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.

Table D-18 Radiological Latent Cancer Fatalities from Incident-Free Rail Transportation of Radioactive Materials

Material	Route			In-Transit			Crew		
		Maximum Individual	Crew	Public Off-Link	Public On-Link	Public Stop	Loading	Total Public	Total Worker
Feed Material in Type 48X Cylinder	Port Hope, ON	7×10^{-9}	4×10^{-4}	3×10^{-4}	2×10^{-5}	8×10^{-2}	9×10^{-4}	8×10^{-2}	1×10^{-3}
Feed Material in Type 48Y Cylinder	Port Hope, ON	5×10^{-9}	3×10^{-4}	2×10^{-4}	2×10^{-5}	6×10^{-2}	5×10^{-4}	6×10^{-2}	8×10^{-4}
Feed Material in Type 48X Cylinder	Metropolis, IL	7×10^{-9}	3×10^{-4}	2×10^{-4}	1×10^{-5}	8×10^{-2}	9×10^{-4}	8×10^{-2}	1×10^{-3}
Feed Material in Type 48Y Cylinder	Metropolis, IL	5×10^{-9}	2×10^{-4}	1×10^{-4}	9×10^{-6}	6×10^{-2}	5×10^{-4}	6×10^{-2}	7×10^{-4}
Product in Type 30B Cylinder	Columbia, SC	9×10^{-10}	4×10^{-5}	4×10^{-5}	3×10^{-6}	1×10^{-2}	2×10^{-4}	1×10^{-2}	2×10^{-4}
Product in Type 30B Cylinder	Wilmington, NC	9×10^{-10}	5×10^{-5}	4×10^{-5}	3×10^{-6}	1×10^{-2}	2×10^{-4}	1×10^{-2}	2×10^{-4}
Product in Type 30B Cylinder	Richland, WA	9×10^{-10}	5×10^{-5}	3×10^{-5}	3×10^{-6}	1×10^{-2}	2×10^{-4}	1×10^{-2}	2×10^{-4}
DUF_6 in Type 48Y Cylinder	Paducah, KY	1×10^{-9}	4×10^{-5}	3×10^{-5}	2×10^{-6}	1×10^{-2}	3×10^{-3}	1×10^{-2}	3×10^{-3}
DUF_6 in Type 48Y Cylinder	Portsmouth, OH	1×10^{-9}	5×10^{-5}	4×10^{-5}	3×10^{-6}	1×10^{-2}	3×10^{-3}	1×10^{-2}	3×10^{-3}
DUF_6 in Type 48Y Cylinder	Metropolis, IL	1×10^{-9}	5×10^{-5}	3×10^{-5}	2×10^{-6}	1×10^{-2}	3×10^{-3}	1×10^{-2}	3×10^{-3}
Empty Type 48Y Cylinder	Metropolis, IL	3×10^{-9}	7×10^{-5}	5×10^{-5}	4×10^{-6}	3×10^{-2}	1×10^{-3}	3×10^{-2}	1×10^{-3}
Empty Type 48Y Cylinder	Port Hope, ON	3×10^{-9}	9×10^{-5}	9×10^{-5}	8×10^{-6}	3×10^{-2}	1×10^{-3}	3×10^{-2}	1×10^{-3}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to NTS, NV	5×10^{-10}	3×10^{-5}	1×10^{-5}	1×10^{-6}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}

Material	Route	Maximum Individual	In-Transit Crew	In-Transit Public Off-Link	In-Transit Public On-Link	Public Stop	Crew Loading	Total Public	Total Worker
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to Clive, UT	5×10^{-10}	3×10^{-5}	1×10^{-5}	1×10^{-6}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to NTS, NV	5×10^{-10}	3×10^{-5}	1×10^{-5}	2×10^{-6}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to Clive, UT	5×10^{-10}	3×10^{-5}	1×10^{-5}	1×10^{-6}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Metropolis, IL, to Clive, UT	5×10^{-10}	3×10^{-5}	9×10^{-6}	9×10^{-7}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Clive, UT	5×10^{-10}	3×10^{-5}	1×10^{-5}	1×10^{-6}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Hanford, WA	5×10^{-10}	3×10^{-5}	2×10^{-5}	2×10^{-6}	6×10^{-3}	7×10^{-5}	6×10^{-3}	1×10^{-4}
CaF_2 in Bulk Bags	Clive, UT	1×10^{-9}	5×10^{-5}	2×10^{-5}	2×10^{-6}	1×10^{-2}	2×10^{-6}	1×10^{-2}	5×10^{-5}
CaF_2 in Bulk Bags	Hanford, WA	1×10^{-9}	6×10^{-5}	3×10^{-5}	3×10^{-6}	1×10^{-2}	2×10^{-6}	1×10^{-2}	6×10^{-5}
Solid Waste in 55-Gallon Drums	Barnwell, SC	2×10^{-11}	7×10^{-7}	6×10^{-7}	5×10^{-8}	2×10^{-4}	4×10^{-6}	2×10^{-4}	4×10^{-6}
Solid Waste in 55-Gallon Drums	Clive, UT	2×10^{-11}	7×10^{-7}	3×10^{-7}	3×10^{-8}	2×10^{-4}	4×10^{-6}	2×10^{-4}	4×10^{-6}
Solid Waste in 55-Gallon Drums	Hanford, WA	2×10^{-11}	9×10^{-7}	4×10^{-7}	5×10^{-8}	2×10^{-4}	4×10^{-6}	2×10^{-4}	4×10^{-6}
Solid Waste in 55-Gallon Drums	Oak Ridge, TN	2×10^{-11}	6×10^{-7}	6×10^{-7}	4×10^{-8}	2×10^{-4}	4×10^{-6}	2×10^{-4}	4×10^{-6}
		Range							
Feed Material	Low	5×10^{-9}	2×10^{-4}	1×10^{-4}	9×10^{-6}	6×10^{-2}	5×10^{-4}	6×10^{-2}	7×10^{-4}
Feed Material	High	7×10^{-9}	4×10^{-4}	3×10^{-4}	2×10^{-5}	8×10^{-2}	9×10^{-4}	8×10^{-2}	1×10^{-3}

Material	Route	Maximum Individual	In-Transit Crew	Public Off-Link	Public On-Link	Public Stop	Crew Loading	Total Public	Total Worker
Product	Low	9×10^{-10}	4×10^{-5}	3×10^{-5}	3×10^{-6}	1×10^{-2}	2×10^{-4}	1×10^{-2}	2×10^{-4}
	High	9×10^{-10}	5×10^{-5}	4×10^{-5}	3×10^{-6}	1×10^{-2}	2×10^{-4}	1×10^{-2}	2×10^{-4}
Disposition of Depleted Uranium	Low	5×10^{-10}	3×10^{-5}	9×10^{-6}	9×10^{-7}	6×10^{-3}	2×10^{-6}	6×10^{-3}	5×10^{-5}
	High	1×10^{-9}	6×10^{-5}	4×10^{-5}	3×10^{-6}	1×10^{-2}	3×10^{-3}	1×10^{-2}	3×10^{-3}
Waste	Low	2×10^{-11}	6×10^{-7}	3×10^{-7}	3×10^{-8}	2×10^{-4}	4×10^{-6}	2×10^{-4}	4×10^{-6}
	High	2×10^{-11}	9×10^{-7}	6×10^{-7}	5×10^{-8}	2×10^{-4}	4×10^{-6}	2×10^{-4}	4×10^{-6}
Empty Cylinders	Low	3×10^{-9}	7×10^{-5}	5×10^{-5}	4×10^{-6}	3×10^{-2}	1×10^{-3}	3×10^{-2}	1×10^{-3}
	High	3×10^{-9}	9×10^{-5}	9×10^{-5}	8×10^{-6}	3×10^{-2}	1×10^{-3}	3×10^{-2}	1×10^{-3}
Total Impact	Low	9×10^{-9}	3×10^{-4}	2×10^{-4}	2×10^{-5}	1×10^{-1}	2×10^{-3}	1×10^{-1}	2×10^{-3}
	High	1×10^{-8}	5×10^{-4}	5×10^{-4}	4×10^{-5}	1×10^{-1}	6×10^{-3}	1×10^{-1}	6×10^{-3}

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Table D-19 Radiological Latent Cancer Fatalities from Accidents During Rail Transportation of Radioactive Materials

Material	Route	Ground	Inhaled	Resuspended Soil	Cloud Shine	Total Risk of LCF
Feed Material in Type 48X Cylinder	Port Hope, ON	3×10^{-7}	2×10^{-1}	3×10^{-2}	3×10^{-11}	3×10^{-1}
Feed Material in Type 48Y Cylinder	Port Hope, ON	3×10^{-7}	2×10^{-1}	3×10^{-2}	3×10^{-11}	3×10^{-1}
Feed Material in Type 48X Cylinder	Metropolis, IL	1×10^{-7}	1×10^{-1}	1×10^{-2}	1×10^{-11}	1×10^{-1}
Feed Material in Type 48Y Cylinder	Metropolis, IL	1×10^{-7}	1×10^{-1}	1×10^{-2}	1×10^{-11}	1×10^{-1}
Product in Type 30B Cylinder	Columbia, SC	2×10^{-7}	1×10^{-1}	8×10^{-3}	7×10^{-12}	1×10^{-1}
Product in Type 30B Cylinder	Wilmington, NC	2×10^{-7}	2×10^{-1}	9×10^{-3}	7×10^{-12}	2×10^{-1}
Product in Type 30B Cylinder	Richland, WA	2×10^{-7}	1×10^{-1}	9×10^{-3}	6×10^{-12}	1×10^{-1}
DUF_6 in Type 48Y Cylinder	Paducah, KY	3×10^{-7}	2×10^{-1}	6×10^{-3}	6×10^{-11}	2×10^{-1}
DUF_6 in Type 48Y Cylinder	Portsmouth, OH	5×10^{-7}	4×10^{-1}	1×10^{-2}	1×10^{-10}	4×10^{-1}
DUF_6 in Type 48Y Cylinder	Metropolis, IL	3×10^{-7}	2×10^{-1}	5×10^{-3}	6×10^{-11}	2×10^{-1}
Empty Type 48Y Cylinder	Metropolis, IL	2×10^{-13}	1×10^{-2}	5×10^{-2}	5×10^{-17}	6×10^{-2}
Empty Type 48Y Cylinder	Port Hope, ON	4×10^{-13}	2×10^{-2}	1×10^{-1}	1×10^{-16}	1×10^{-1}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to NTS, NV	4×10^{-8}	7×10^{-5}	1×10^{-5}	7×10^{-13}	9×10^{-5}
Depleted U_3O_8 in Bulk Bags	Paducah, KY, to Clive, UT	3×10^{-8}	6×10^{-5}	1×10^{-5}	6×10^{-13}	7×10^{-5}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to NTS, NV	6×10^{-8}	1×10^{-4}	2×10^{-5}	1×10^{-12}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Portsmouth, OH, to Clive, UT	5×10^{-8}	1×10^{-4}	2×10^{-5}	1×10^{-12}	1×10^{-4}
Depleted U_3O_8 in Bulk Bags	Metropolis, IL, to Clive, UT	8×10^{-8}	2×10^{-4}	2×10^{-5}	2×10^{-12}	2×10^{-4}
Depleted U_3O_8 in Bulk Bags	Clive, UT	4×10^{-8}	7×10^{-5}	2×10^{-5}	7×10^{-13}	9×10^{-5}
Depleted U_3O_8 in Bulk Bags	Hanford, WA	7×10^{-8}	1×10^{-4}	3×10^{-5}	1×10^{-12}	2×10^{-4}

Material	Route	Ground	Inhaled	Resuspended Soil	Cloud Shine	Total Risk of LCF
CaF_2 in Bulk Bags	Clive, UT	7×10^{-13}	3×10^{-9}	1×10^{-8}	2×10^{-18}	1×10^{-8}
CaF_2 in Bulk Bags	Hanford, WA	1×10^{-12}	5×10^{-9}	2×10^{-8}	4×10^{-18}	3×10^{-8}
Solid Waste in 55-Gallon Drums	Barnwell, SC	5×10^{-11}	2×10^{-5}	5×10^{-5}	3×10^{-15}	8×10^{-5}
Solid Waste in 55-Gallon Drums	Clive, UT	2×10^{-11}	1×10^{-5}	3×10^{-5}	2×10^{-15}	4×10^{-5}
Solid Waste in 55-Gallon Drums	Hanford, WA	4×10^{-11}	2×10^{-5}	5×10^{-5}	3×10^{-15}	8×10^{-5}
Solid Waste in 55-Gallon Drums	Oak Ridge, TN	4×10^{-11}	2×10^{-5}	5×10^{-5}	3×10^{-15}	7×10^{-5}
Range						
Feed Material	Low	1×10^{-7}	1×10^{-1}	1×10^{-2}	1×10^{-11}	1×10^{-1}
	High	3×10^{-7}	2×10^{-1}	3×10^{-2}	3×10^{-11}	3×10^{-1}
Product	Low	2×10^{-7}	1×10^{-1}	8×10^{-3}	6×10^{-12}	1×10^{-1}
	High	2×10^{-7}	2×10^{-1}	9×10^{-3}	7×10^{-12}	2×10^{-1}
Disposition of Depleted Uranium	Low	7×10^{-13}	3×10^{-9}	1×10^{-8}	2×10^{-18}	1×10^{-8}
	High	5×10^{-7}	4×10^{-1}	1×10^{-2}	1×10^{-10}	4×10^{-1}
Waste	Low	2×10^{-11}	1×10^{-5}	3×10^{-5}	2×10^{-15}	4×10^{-5}
	High	5×10^{-11}	2×10^{-5}	5×10^{-5}	3×10^{-15}	8×10^{-5}
Empty Cylinders	Low	2×10^{-13}	1×10^{-2}	5×10^{-2}	5×10^{-17}	6×10^{-2}
	High	4×10^{-13}	2×10^{-2}	1×10^{-1}	1×10^{-16}	1×10^{-1}
Total Impact	Low	3×10^{-7}	2×10^{-1}	7×10^{-2}	2×10^{-11}	3×10^{-1}
	High	1×10^{-6}	8×10^{-1}	2×10^{-1}	1×10^{-10}	1

ON - Ontario, Canada. IL - Illinois. SC - South Carolina. NC - North Carolina.
WA - Washington. KY - Kentucky. OH - Ohio. UT - Utah.
TN - Tennessee. NV - Nevada. NTS - Nevada Test Site.

D.5 Chemical Impact Analysis Resulting from Accidents with UF_6 Cylinders

If UF_6 is released to the atmosphere, it reacts with water vapor in the air to form hydrofluoric acid and uranyl fluoride (UO_2F_2), independent of the enrichment of the UF_6 (i.e., natural, enriched, or depleted). The products are chemically toxic to humans. Hydrofluoric acid is extremely corrosive and can damage the lungs and cause death if inhaled at high enough concentrations. In addition, uranium is a heavy metal that, in addition to being radioactive, can have toxic chemical effects (primarily on the kidneys) if it enters by way of ingestion and/or inhalation (DOE, 2004a).

DOE analyzed the chemical impacts from the transportation of DUF_6 from the East Tennessee Technology Park to the Portsmouth and Paducah Gaseous Diffusion Plants (DOE, 2004a; DOE, 2004b). These results were used to estimate the chemical impacts associated with the proposed NEF. Their results are applicable because the chemical impacts would not vary with: (1) the shipping route, (2) the amount of enrichment, and (3) similar shipping containers. Because DOE postulated a hypothetical accident that could occur at any location, the results are not route dependent. DOE evaluated chemical impacts to rural (6 persons per square kilometer [15 persons per square mile]), suburban (719 persons per square kilometer [1,798 persons per square mile]), and urban (1,600 persons per square kilometer [4,000 persons per square mile]) areas. In addition, the proposed NEF would use the same containers (Type 48Y cylinders) that DOE evaluated. Chemical impacts are not dependent on enrichment of the uranium, only on the amount of uranium in the container.

The toxic effects, or chemical impacts, can be categorized as adverse health effects or irreversible adverse health effects. An adverse health effect includes respiratory irritation or skin rash associated with lower chemical concentrations. An irreversible adverse health effect generally occurs at higher chemical concentrations and is permanent in nature. Irreversible adverse health effects include death, impaired organ function (such as central nervous system or lung damage), and other effects that may impair daily functions. Of those individuals receiving an irreversible adverse health effect, approximately 1 percent or less would die from it (LES, 2005).

Acute effects evaluated were assumed to exhibit a threshold nonlinear relationship with exposures; that is, some low level of exposure can be tolerated without inducing a health effect. Chemical-specific threshold concentrations were developed for potential adverse effects and potential irreversible adverse effects. To address maximally exposed individuals, the locations of maximum chemical concentration were identified for shipments with the largest potential releases. Estimates of exposure duration at those locations were obtained from modeling output and were used to assess whether maximally exposed individual exposure to uranium and hydrofluoric acid would exceed the criteria for potential irreversible adverse effects. The primary exposure pathway would be inhalation as it results in the highest exposure for the chemicals. Acute effects from ingestion and absorption through the skin would be less than those from inhalation (DOE 2004a; DOE 2004b).

DOE used the FIREPLUME model to simulate the dispersion of toxic gases and particulates from transportation accidents involving UF_6 fires. The model can simulate three phases that UF_6 fires may undergo. These include (1) the instantaneous puff that is released in a hydraulic rupture, (2) the emissions from the continuous fire that occurs afterwards, and (3) the emissions from the cool-down phase in which releases decline to zero as the temperature of the fire declines. The location of the maximally exposed individual is assumed to be 30 meters (100 feet) or farther from the release point (DOE, 2004a, DOE 2004b).

DOE evaluated chemical impacts for both neutral and stable meteorological conditions. Neutral meteorological conditions are defined as Pasquill stability class D conditions (wind speed of 4 meters per second [9 miles per hour]) while stable meteorological conditions are defined as Pasquill stability class F (wind speed of 1 meter per second [2 miles per hour]) (DOE 2004a, DOE 2004b). Results for stable meteorological conditions are presented in this appendix because the impacts are greater than for neutral conditions and are therefore bounding.

The potential transportation chemical consequences of an accident involving UF_6 are shown in Table D-20 for both truck and rail. This table also shows the potential chemical consequences of a severe transportation accident assumed to have occurred involving the transportation of depleted U_3O_8 from a DUF_6 conversion facility to a disposal facility. The probability that this accident could occur is very remote. The results show that while adverse chemical impacts would be high, few individuals would experience irreversible adverse health effects and less than one death would be expected.

Table D-20 Potential Chemical Consequences to the Population from Severe Transportation Accidents

Source	Mode	Rural	Suburban	Urban
Number of Persons with the Potential for Adverse Health Effects				
DUF_6	Truck	6	760	1,700
	Rail	110	13,000	28,000
Depleted U_3O_8 (in bulk bags)	Truck	0	12	28
	Rail	0	47	103
Number of Persons with the Potential for Irreversible Adverse Health Effects[a]				
DUF_6	Truck	0	1	3
	Rail	0	2	4
Depleted U_3O_8 (in bulk bags)	Truck	0	5	10
	Rail	0	17	38

[a] Exposure to hydrofluoric acid or uranium compounds is estimated to result in fatality to approximately 1 percent or less of those persons experiencing irreversible adverse effects.
Sources: DOE, 2004a; DOE, 2004b.

D.6 Uncertainty in Transportation Risk Assessment

There are many sources of uncertainty in assessing the risks of transporting radioactive materials to and from the proposed NEF. Several factors that can be quantified are: routing of the material, the shipping container characteristics, mode of transport, and source or destination of the material. Each of these sources of uncertainty are discussed below.

D.6.1 Routing of Radioactive Material

There are many varying routes for the shipments of the radioactive materials to and from the proposed NEF. The WebTragis computer code simplifies the routing choices by allowing the analyst to select various routing restrictions. These can range from no restrictions to Highway Route Controlled Quantity restrictions. Choices can be made between shortest route, fastest route, block various routes, etc. For this EIS, the NRC staff examined two different types of routing: the shortest with commercial, hazardous, and radioactive restrictions and Highway Route Controlled Quantity restrictions one of the most restrictive route specifications. For shipments in the eastern part of the US, the two different routes did not vary to any significant amount. For shipments to Clive, Utah; Richland and Hanford, Washington; and the Nevada Test Site, Nevada, the two different routes could vary significantly.

A comparison of the RADTRAN 5 results for comparable shipments indicated that for all but one route, Highway Route Controlled Quantity routing yields the greater impacts. For this one route, the variation impacts were less than 1 percent. Therefore, the NRC staff used the Highway Route Controlled Quantity routing.

D.6.2 Shipping Container Characteristics

The characteristics of the shipping container are important in the assessment of both the incident-free and the accident impacts. The incident-free impact is determined by the direct radiation along the side of the shipping container and the length of the container. The accident impacts are determined by the release fraction for each accident severity class. Historically, NUREG-0170 (NRC, 1977) was developed to provide background material for a review by the NRC of regulations dealing with the transportation of radioactive materials. In 2002, DOE prepared a resource handbook for transportation risk assessment (DOE, 2002). That document presented a review of the historical assessments, transportation models, and a compilation of supporting data parameters and generally accepted assumptions. DOE/EA-1290 also evaluated the shipments of DUF_6 in Type 48Y containers; however, the release fractions were about one quarter of the DOE handbook values (DOE, 1999).

The NRC staff chose to use the release fractions from the DOE handbook for Type A containers as being more conservative than those presented in DOE/EA-1290.

D.6.3 Mode of Transport

The use of truck or rail can affect the impact analysis in several different ways. First the number of trips can be reduced greatly by the use of railroads rather than trucks. Therefore, the impact from vehicle emissions and accidents involving trains is reduced with the use of railroads. However, since a railcar can transport more material, the impacts from the release of radioactive material during an accident would be greater. The capacity of trucks can also affect the impact analysis. In a similar way, the larger the truck, the more material can be transported, resulting in fewer trips but higher impacts from the release of radioactive material during an accident.

The NRC staff evaluated the transportation impacts from the use of both trucks and rail.

D.6.4 Source or Destination of Radioactive Material

The source or destination of the radioactive material can also affect the transportation impact analysis. For example, as discussed in section D.4.2, it is not expected that all of the feed material would come exclusively from Port Hope, Ontario, Canada, or from Metropolis, Illinois. It is a reasonable assumption that some feed would come from Port Hope and some would come from Metropolis. Therefore, the impact from the transportation of feed material would be somewhere between the impacts evaluated for Port Hope and Metropolis.

D.7 References

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APPENDIX E
AIR-QUALITY ANALYSIS

This appendix presents the analysis for determining the visibility impacts from operation of the Louisiana Energy Services (LES) proposed National Enrichment Facility (NEF) site and an assessment of the potential impacts due to high wind speed conditions.

E.1 Analysis for the Potential for Fog from the Proposed NEF

There is the potential for visual impacts in the local area from fog that could be generated by the cooling towers during operation under the proper weather conditions. Conditions are considered to be favorable for fog formation when humidity is high, wind speed is low, and atmosphere is stable. One concern is that under low wind speed conditions (less than 3 meters per second [9.8 feet per second]) and high relative humidity (greater than 95 percent), the cooling towers might significantly reduce visibility due to the generation of fog. To investigate potential visual impact from the cooling towers, meteorological data were analyzed for these conditions. Hourly surface observations at Midland-Odessa, Texas, for the five most recent years of data were used in this analysis as recommended by the U.S. Environmental Protection Agency (NCDC, 1998). These meteorological data were used as input in the air-quality modeling.

Hourly observations of wind speed and relative humidity for Midland-Odessa, Texas, from the International Surface Weather Observations database for the five-year period from 1987 through 1991 were examined. From all observations within that period, relative humidity was higher than 95 percent in 527 cases (or 1.2 percent per year). Figure E-1 shows the wind speed for such conditions. From 527 observations when relative humidity was higher than 95 percent, only 193 cases were observed when wind speed was below 3 meters per second (9.8 feet per second) and stability was neutral (D), stable (E), or very stable (F). This corresponds to less than 0.5 percent of the total number of hours per year.

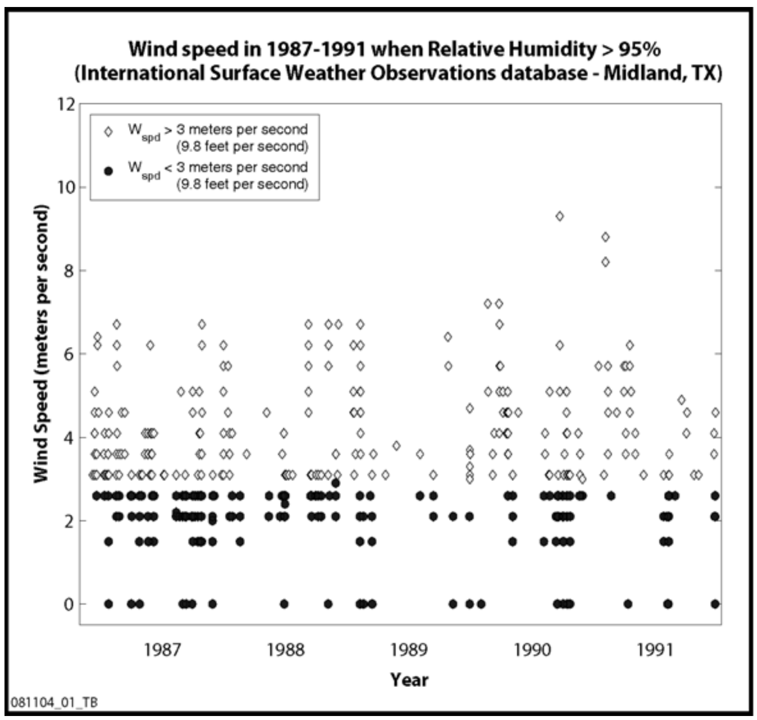

Figure E-1 Wind Speed in High Relative Humidity Conditions for Midland-Odessa, Texas (NCDC, 1998)

To determine time of day and seasonality for atmospheric conditions favorable for fog formation, frequency distributions were generated for all observations when relative humidity is greater than 95 percent, wind speed is less than 3 meters per second (9.8 feet per second), and stability is D, E, or F. Figure E-2 shows a histogram of hour of day and Figure E-3 shows a histogram of month of year for such conditions for all hours in the years 1987 through 1991. The figures show that such atmospheric conditions occur mostly early in the morning or late in the evening.

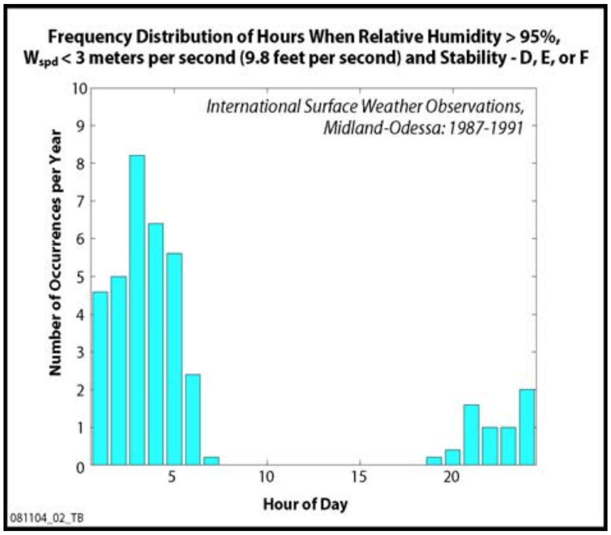

Figure E-2 Histogram of Hour of Day (1987-1991) for Favorable Conditions for Fog (NCDC, 1998)

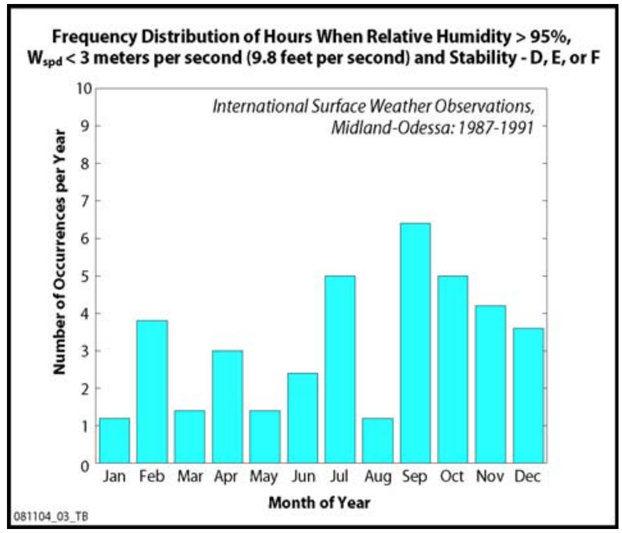

Figure E-3 Histogram of Month of Year (1987-1991) for Favorable Conditions for Fog (NCDC, 1998)

Another concern is that the cooling towers may increase the probability of freezing and icing on the ground. To determine time of day and seasonality for atmospheric conditions favorable to such conditions, frequency distributions were generated for all observations when relative humidity was greater than 95 percent, wind speed was less than 3 meters per second (9.8 feet per second); stability was D, E, or F; and temperature was below 0ºC (32ºF). Figure E-4 shows a histogram of hour of day and Figure E-5 shows a histogram of month of year for such conditions for all hours in the years 1987 through 1991. The figures show that such atmospheric conditions occur mostly early in the morning or late in the evening in late fall and winter (November through February).

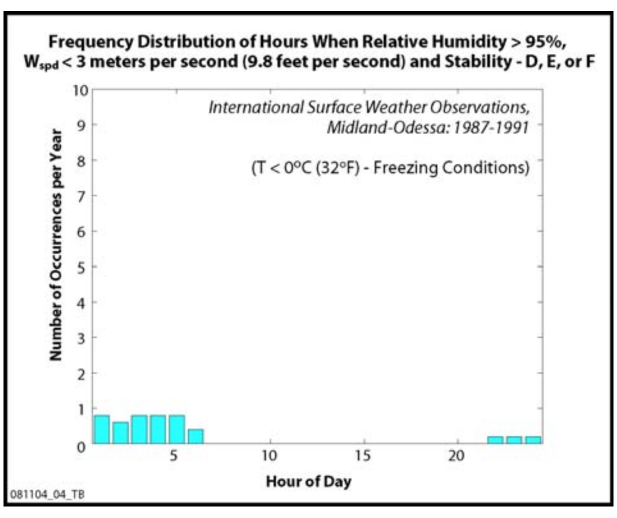

Figure E-4 Histogram of Hour of Day for Favorable Conditions for Icing on the Ground (NCDC, 1998)

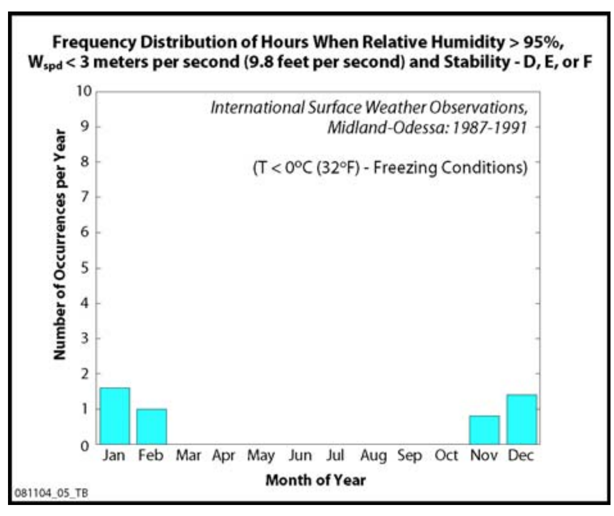

Figure E-5 Histogram of Month of Year for Favorable Conditions for Icing on the Ground (NCDC, 1998)

E.2 Analysis of the Potential Effects of High Winds

The analysis of meteorological observations indicates the presence of high prevailing southerly winds in this area. There is a concern that emissions from the proposed NEF plant could be carried by these strong southerly winds over Hobbs, New Mexico, in less than 1 hour. Five years of hourly meteorological observations at the Midland-Odessa National Weather Service Station were analyzed to determine frequency of occurrence of strong southerly winds. Figure E-6 shows frequency distribution of wind direction for all hours in 1987-1991 (upper panel), winds greater than 8 meters per second (26.2 feet per second) but less than 14 meters per second (45.9 feet per second) (middle panel), and only for those hours when wind speed exceeds 14 meters per second (45.9 feet per second) (lower panel). These strong winds fall into a category “gale” (greater than 15 meters per second [49.2 feet per second]) or “storm” (greater than 25 meters per second [82.0 feet per second]) type of winds. Wind speed of 14 meters per second (45.9 feet per second) corresponds to 1 hour of travel time, so the trajectory can reach a 50-kilometer (31.1-mile) distance.

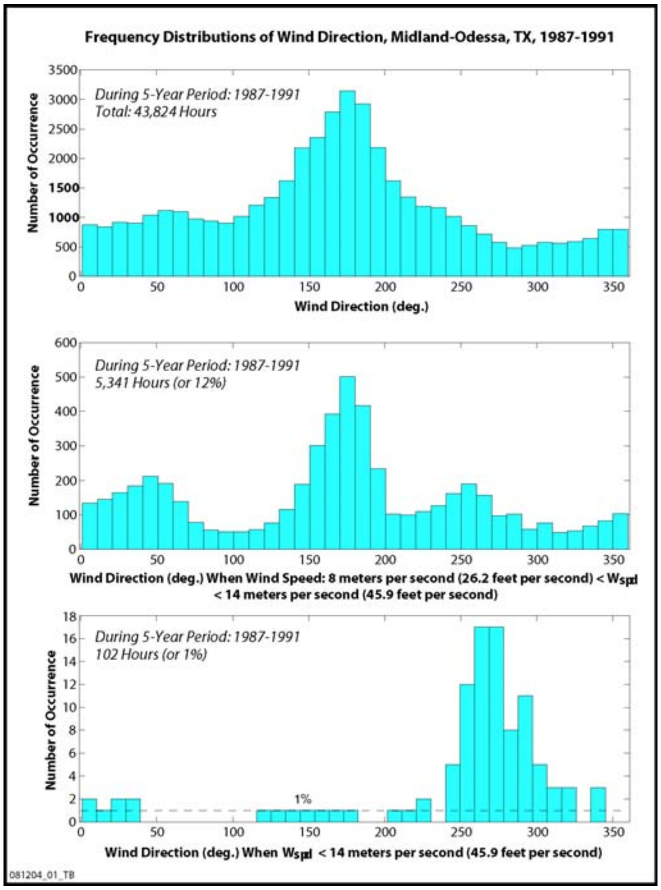

Figure E-6 Frequency Distribution of Wind Direction for All Hours (1987-1991)

When wind speed is less than 14 meters per second (45.9 feet per second) but greater than 8 meters per second (26.2 feet per second), the trajectory can reach a 25-kilometer (15.5-mile) distance or more (and possibly reach Hobbs, New Mexico, in 1 hour). As shown in Figure E-6, the histogram of wind direction for all hours (all wind speeds) has a maximum at 180 degrees (southerly winds), whereas the histogram of wind direction for hours when wind speeds exceed 14 meters per second (45.9 feet per second) has a maximum at 270 degrees (westerly winds). This indicates that strong winds (category “gale” or “storm”) in the study area are predominately from the west.

However, these are relatively rare events—statistical analysis shows that only for 1 percent of the time in a 5-year period (102 hours total) are winds greater than 14 meters per second (45.9 feet per second) (i.e., category “gale” or “storm”). To determine atmospheric conditions associated with these strong westerly winds in the area, histograms of other related parameters were created. Figures E-7a and E-7b show histograms of hour, day, month of year, and stability class for all hours in 1987-1991 when (a) winds are greater than 8 meters per second (26.2 feet per second) but less than 14 meters per second (45.9 feet per second), and (b) winds are stronger than 14 meters per second (45.9 feet per second). As can be seen from these figures, the very strong westerly winds occur mostly in the afternoon in spring under neutral stability conditions. Strong, but not extreme wind speeds between 8 meters per second (26.2 feet per second) and 14 meters per second (45.9 feet per second) (i.e., below category "gale") are mostly from the south. Total number of hours when winds are strong, but still below the "gale" category, is approximately 12 percent of all hours in 1987-1991.

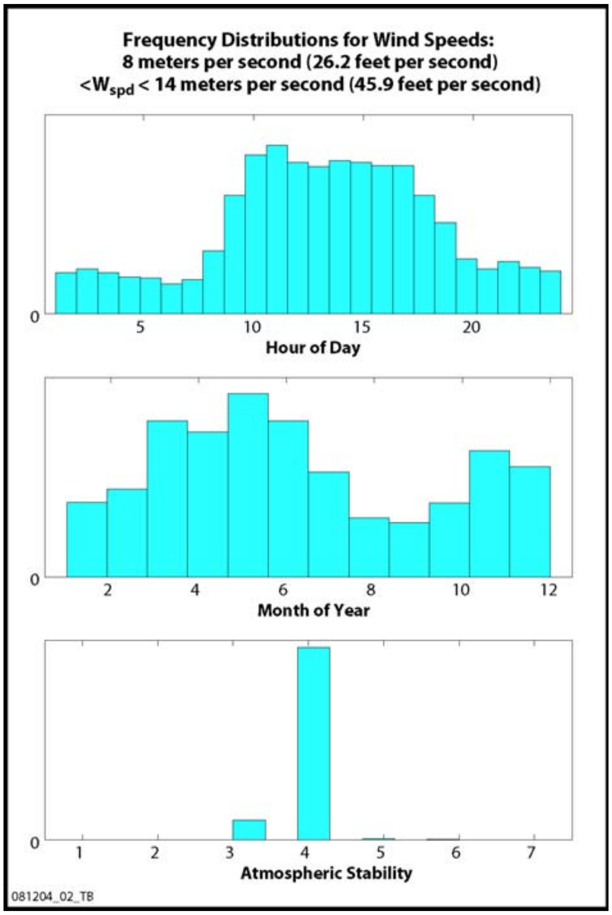

Figure E-7a Histogram of Occurrences of Strong Winds

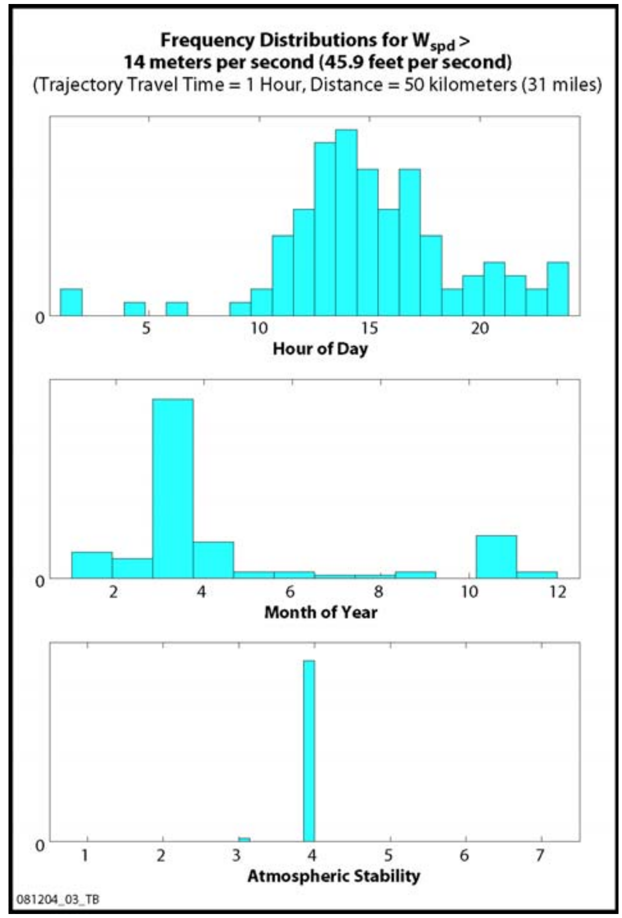

Figure E-7b Histogram of Occurrences of Extreme Winds

To estimate spatial gradient in potential pollutant concentration from the proposed NEF, a sensitivity test was conducted. This sensitivity test helps to visualize possible transport of material from the proposed NEF during the strong wind episodes. A surface release was simulated using the Industrial Source Complex Short-Term dispersion model (EPA, 1995) using data from March 1, 1991. This was a typical "high wind case" when winds were above 14 meters per second (45.9 feet per second) from 11 a.m. until 6 p.m., mostly from the west-southwest, and stability was neutral. The results from this simulation are shown in Figure E-8. Average 24-hour concentrations are shown as a shaded image overlaid on a schematic map of the study area. This figure shows that a narrow plume would extend to the east from the proposed NEF source.

Another sensitivity test was conducted to investigate possible effects of strong southerly but not extreme winds (again between 8 meters per second [26.2 feet per second] and 14 meters per second [45.9 feet per second]) on pollutant concentrations, when pollutants may possibly reach Hobbs, New Mexico. March 10, 1991, was selected for this simulation and 24-hour average concentrations were estimated. The wind speed was approximately 10 meters per second (32.8 feet per second) from 9 a.m. until 10 p.m., mostly from the south, and stability was neutral. Figure E-9 shows the results from this simulation. Average 24-hour concentrations are shown as a shaded image overlaid on a schematic map of the study area. The figure shows a narrow plume extending to the north from the source.

These sensitivity tests indicate that pollutants may possibly reach Hobbs, New Mexico, during strong wind episodes. However, atmospheric conditions when winds can be characterized as “gale” or “storm” are rare, and levels of concentrations are expected to be significantly lower at distances greater than 25 kilometers (15.5 miles). Spatial gradients in modeled pollutant concentrations were also estimated. A sensitivity test was conducted for the same day (March 10, 1991), with winds from the south, so the plume extends to the north from the proposed NEF source. The results from this simulation are shown in Figure E-10. The figure shows the decrease in concentrations at the plume centerline due to dispersion processes as a function of distance from the source. As can be seen from the figure, the concentration decreases by a factor of 1,000 when the possible plume from the proposed NEF reaches Hobbs, New Mexico.

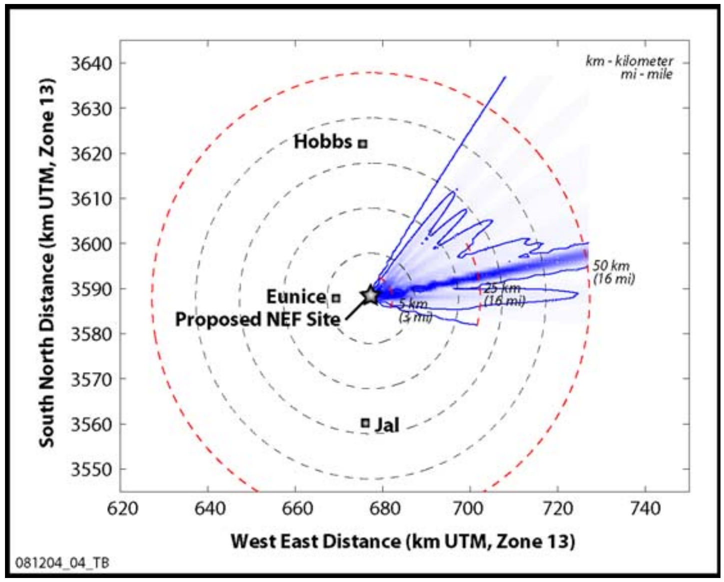

Figure E-8 Average 24-Hour Concentrations of Pollutants in Extreme Winds from the West-Southwest

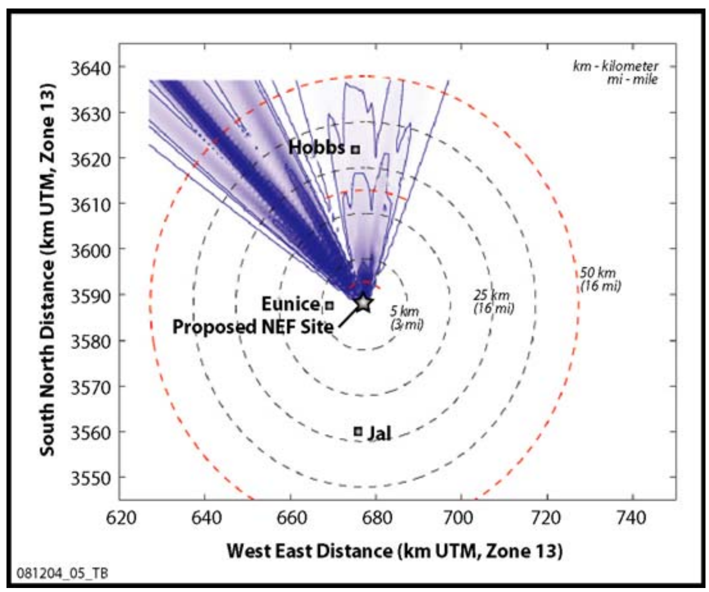

Figure E-9 Average 24-Hour Concentrations of Pollutants in Strong Southerly Winds

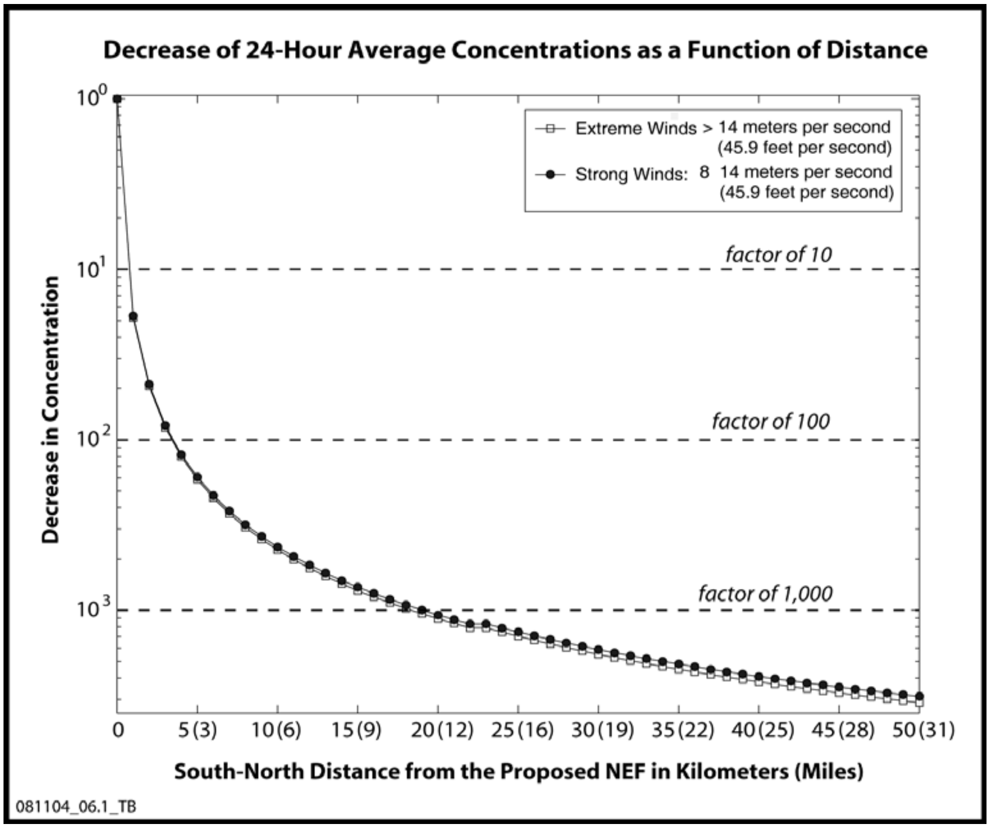

Figure E-10 Pollutant Concentrations at the Plume Centerline as a Function of Distance from the Proposed NEF

E.3 References

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APPENDIX F
SOCIOECONOMICS

F.1 Impacts

This appendix presents the potential socioeconomic impacts of the Louisiana Energy Services (LES) proposed National Enrichment Facility (NEF) using cost data for local construction and operations (LES, 2005). These data and Regional Input-Output Modeling System (RIMS II) final demand multipliers, specifically developed for the 120-kilometer (75-mile) region of influence, were used to estimate impacts on output, earnings, and jobs (BEA, 1997). These final demand multipliers and results (in 2004 dollars) are shown in Table F-1 for construction and Table F-2 for operations. For the output and earnings multipliers, each multiplier indicates the change in output or earnings for each $1 change in final demand. The jobs multiplier indicates the additional jobs created for each $1 million dollars in local spending.

Table F-1 Total Estimated Average Annual Impact of the Proposed NEF Construction

Good/Service	Local Purchases	Final Demand Multipliers			Total Impact		
		Output	Earnings	Jobs	Output ($1,000)	Earnings ($1,000)	Jobs
Concrete	$647	1.7112	0.5087	16.4	$1,070	$329	10
Reinforcing Steel	$65	1	0	0	$65	$0	0
Structural Steel	$259	1	0	0	$259	$0	0
Lumber	$32	1	0	0	$32	$0	0
Site Preparation	$2,588	1.6002	0.4459	13.7	$4,141	$1,154	34
Transportation	$259	1.7782	0.5066	17.7	$460	$131	4
Subcontracts							
Precast Concrete	$2,588	1.6002	0.4459	13.7	$4,141	$1,154	34
Architectural - Building	$5,175	1.6002	0.4459	13.7	$8,282	$2,308	69
Equipment	$3,235	1.6002	0.4459	13.7	$5,176	$1,442	43
Mechanical/Piping/ Heating Ventilation and Air Conditioning	$9,704	1.6002	0.4459	13.7	$15,528	$4,327	129
Electrical Controls	$9,704	1.6002	0.4459	13.7	$15,528	$4,327	129
Payroll	$16,066	0.8182	0.2216	8.4	$13,145	$3,560	130
Total	**$50,320**				**$67,863**	**$18,732**	**582**

Sources: LES, 2005; BEA, 2004.

Table F-2 Total Estimated Average Annual Impact of the Proposed NEF Operations

Good/Service	Local Purchases ($1,000)	Final Demand Multipliers			Total Impact		
		Output	Earnings	Jobs	Output ($1,000)	Earnings ($1,000)	Jobs
Landscaping	$78	1.6154	0.7509	38.2	$125	$58	3
Protective Clothing	$31	1.4698	0.3211	13.4	$46	$10	0
Lab Chemicals	$52	1.7137	0.3411	6.5	$89	$18	0
Plant Spare Equipment	$176	1.4774	0.3783	10.7	$260	$67	2
Office Equipment	$166	1	0	0	$166	$0	0
Engineered Parts	$155	1.6005	0.5761	16.6	$248	$89	2
Electrical Parts	$228	1.5052	0.4576	14.9	$343	$104	3
Natural Gas	$58	2.8977	0.3734	7.3	$168	$22	0
Waste Water	$96	1.7537	0.4507	12.0	$169	$43	1
Solid Waste Disposal	$3	1.7537	0.4507	12.0	$5	$1	0
Insurance	$0	1.5546	0.5486	17.7	$0	$0	0
Catering	$52	1.5453	0.4801	30.2	$80	$25	2
Building Maintenance	$383	1.5772	0.4727	14.8	$604	$181	5
Custodial Services	$259	1.7909	0.7261	41.7	$463	$188	10
Professional Services	$186	1.6377	0.6922	18.8	$305	$129	3
Security Services	$518	1.4976	0.6315	28.9	$775	$327	14
Mail & Document Services	$104	1.6370	0.7074	19.5	$169	$73	2
Office Supplies	$145	1	0	0	$145	$0	0
Electric Services	$7,246	1.5129	0.2892	5.5	$10,962	$2,095	38
Payroll	$10,890	0.8182	0.2216	8.4	$8,910	$2,413	88
Total	**$20,824**				**$24,033**	**$5,844**	**173**

Sources: LES, 2005; BEA, 2004.

F.2 References

(BEA, 1997) Bureau of Economic Analysis. *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II).* U.S. Department of Commerce. Washington, D.C. March 1997.

(BEA, 2004) Bureau of Economic Analysis. *RIMS II Multipliers for the Hobbs, New Mexico, and Odessa-Midland, Texas, Region.* U.S. Department of Commerce. Washington, D.C. March 2004.

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APPENDIX G
ENVIRONMENTAL JUSTICE

G.1 Introduction

This appendix provides additional material for the assessment of the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations resulting from the proposed construction, operation, and decommissioning of the Louisiana Energy Services (LES) proposed National Enrichment Facility (NEF).

Table G-1 presents the detailed census data for the environmental justice review and provides the minority and low-income population data for each census block group within 80 kilometers (50 miles) of the proposed NEF site (USCB, 2002a; USCB, 2002b). Minority and low-income block groups that are shown in bold meet the U.S. Nuclear Regulatory Commission criteria in NUREG-1748 (NRC, 2003); therefore, environmental justice should be considered in greater detail. These criteria are defined as (1) the minority and/or low-income populations exceed 50 percent in a block group or (2) the minority and/or low-income population in the block group is significantly greater than the State or relevant county percentage. This information was used in the environmental justice analysis described in Chapter 3 of this Environmental Impact Statement (EIS).

Table G-1 Census Block Groups Within 80 Kilometers (50 Miles) of the Proposed NEF Site[a]

County/ Tract	Block Group	Persons	Below Poverty Level (%)	White (%)	African American/ Black (%)	American Indian and Alaskan Native (%)	Asian or Other Pacific Islander (%)	Other Race (%)	Two or More Races (%)	Hispanic or Latino (All Races) (%)	Minorities (Racial Minorities Plus White Hispanics) (%)
State of New Mexico		1,819,046	18.4	66.8	2.1	10.2	1.4	19.0	0.6	42.1	55.3
Threshold for Environmental Justice Concerns			38.4	—	22.1	30.2	21.4	39.0	20.6	50.0/42.1	50.0
Eddy County											
000700	1	759	15.1	75.8	0.8	1.3	0.1	21.5	0.5	39.3	41.7
000800	1	654	20.5	65.2	0.3	1.8	0.2	32.3	0.2	**66.8**	**68.6**
000900	1	136	13.9	77.4	0.8	2.7	0.1	18.5	0.6	34.1	37.0
Lea County											
000100	1	935	21.9	52.5	5.2	1.4	1.2	**39.5**	0.2	**65.0**	**72.6**
000100	2	829	28.1	57.2	5.3	2.4	0.5	34.0	0.6	**52.4**	**60.9**
000100	3	682	**54.8**	42.1	3.1	1.0	0.2	**53.1**	0.6	**73.9**	**77.4**
000200	1	677	30.7	64.0	0.7	2.1	0.2	32.3	0.7	**58.5**	**60.7**
000200	2	592	32.9	47.8	6.4	1.9	0.0	**43.1**	0.8	**62.8**	**69.6**
000200	3	585	24.9	67.4	0.5	1.2	0.7	30.3	0.0	*47.7*	**50.4**
000200	4	563	32.9	61.6	2.5	2.0	0.7	32.5	0.7	**55.2**	**59.7**
000200	5	565	**52.1**	42.7	4.3	1.6	0.0	**51.3**	0.2	**71.2**	**75.9**
000300	1	686	30.3	24.8	**39.8**	1.9	0.0	32.8	0.7	**52.9**	**92.3**
000300	2	810	**46.7**	42.2	7.8	2.1	0.0	**47.0**	0.9	**69.0**	**78.8**
000300	3	820	**41.6**	43.7	11.0	1.2	0.4	**43.3**	0.5	**70.1**	**81.8**
000300	4	985	**56.9**	52.8	4.9	0.2	0.4	**41.4**	0.3	**63.4**	**68.9**
000400	1	775	**57.0**	27.5	21.3	1.3	0.3	**48.6**	1.0	**68.0**	**91.0**

County/ Tract	Block Group	Persons	Below Poverty Level (%)	White (%)	African American/ Black (%)	American Indian and Alaskan Native (%)	Asian or Other Pacific Islander (%)	Other Race (%)	Two or More Races (%)	Hispanic or Latino (All Races) (%)	Minorities (Racial Minorities Plus White Hispanics) (%)
000400	2	1,053	25.9	56.1	10.0	1.8	0.8	30.7	0.7	**50.5**	**62.9**
000400	3	661	**42.8**	31.0	21.0	1.1	0.8	**44.8**	1.4	**68.8**	**90.8**
000501	1	781	2.9	86.6	2.1	0.5	1.3	9.1	0.5	12.7	16.9
000501	2	848	7.2	84.3	1.7	3.1	0.1	10.7	0.1	22.8	27.5
000501	3	533	**39.6**	75.1	5.6	2.6	0.8	15.8	0.2	26.1	34.0
000501	4	1,063	16.7	80.1	3.5	1.8	0.9	13.0	0.9	20.9	26.6
000501	5	775	9.8	89.9	1.6	0.9	0.9	6.6	0.1	9.7	13.8
000501	6	718	7.2	83.6	3.5	1.5	0.1	11.0	0.3	18.2	24.0
000501	7	1,381	5.2	87.8	2.6	0.8	1.1	7.2	0.4	12.2	16.6
000502	1	920	25.4	69.0	4.6	1.2	0.0	24.6	0.7	35.9	42.4
000502	2	968	28.2	65.4	4.8	0.8	0.7	28.0	0.3	41.4	47.1
000502	3	1,002	16.9	71.6	6.4	1.4	0.0	20.4	0.3	31.1	38.5
000502	4	810	3.7	86.2	2.6	1.7	2.4	6.4	0.7	11.4	17.9
000502	5	1,052	15.3	77.3	2.5	1.1	0.9	18.1	0.3	25.2	29.6
000502	6	786	31.4	59.3	14.6	0.8	0.1	24.0	1.2	34.5	**50.5**
000600	1	805	4.8	89.7	2.4	1.2	1.4	5.3	0.0	10.8	15.9
000600	2	734	4.3	90.7	1.1	0.8	0.4	6.7	0.3	10.6	12.9
000600	3	901	4.7	76.1	2.1	1.6	0.0	20.0	0.2	30.7	34.2
000600	4	756	22.2	74.2	3.0	0.8	0.7	21.2	0.1	31.0	35.7
000600	5	811	23.0	38.7	14.2	1.0	0.0	**45.4**	0.7	**66.1**	**81.3**
000600	6	957	17.5	48.5	13.4	2.1	0.1	35.3	0.6	**63.3**	**76.9**
000600	7	906	11.4	59.3	7.5	2.8	1.4	28.5	0.6	41.8	**52.8**
000700	1	1,052	7.7	83.2	0.8	1.1	0.7	14.2	0.1	21.5	24.1

County/ Tract	Block Group	Persons	Below Poverty Level (%)	White (%)	African American/ Black (%)	American Indian and Alaskan Native (%)	Asian or Other Pacific Islander (%)	Other Race (%)	Two or More Races (%)	Hispanic or Latino (All Races) (%)	Minorities (Racial Minorities Plus White Hispanics) (%)
000700	2	1,899	1.7	68.6	9.1	3.7	0.7	17.8	0.1	40.7	**54.2**
000700	3	882	13.2	83.8	0.6	1.1	0.6	13.8	0.1	22.3	24.5
000700	4	812	13.8	83.1	0.9	1.6	0.1	14.2	0.1	18.2	20.7
000700	5	1,331	19.0	84.8	1.0	2.0	0.3	11.9	0.0	23.4	26.7
000700	6	1,930	13.7	85.6	1.0	1.3	1.2	10.5	0.4	16.4	19.9
000800	1	850	10.2	75.7	0.5	0.7	0.0	23.2	0.0	32.1	33.6
000800	2	618	3.6	82.0	0.5	1.5	0.2	15.5	0.3	24.8	26.9
000800	3	773	24.1	67.9	2.6	1.7	0.5	27.2	0.1	*48.6*	**52.8**
000800	4	655	25.6	66.3	0.9	0.8	0.5	31.6	0.0	41.2	44.3
000900	1	562	17.8	79.5	0.2	1.1	0.2	18.9	0.2	28.6	30.1
000900	2	726	24.1	57.3	1.4	2.6	0.0	38.3	0.4	**51.1**	**53.9**
000900	3	830	12.5	68.0	0.1	2.3	0.0	28.9	0.7	39.2	41.2
001002	1	819	24.4	53.7	2.0	2.0	0.5	**41.8**	0.1	**55.3**	**58.6**
001002	2	1,357	19.3	64.2	2.5	1.4	0.2	31.6	0.2	*45.8*	49.8
001002	3	975	22.6	60.3	2.1	0.8	1.4	35.4	0.0	**51.7**	**54.6**
001002	4	713	25.3	51.5	3.1	1.7	0.3	**43.3**	0.1	**65.1**	**69.0**
001002	5	945	28.4	53.3	10.5	1.3	0.1	34.8	0.0	**56.9**	**68.9**
001002	6	592	20.2	51.9	3.2	0.5	0.2	**43.9**	0.3	**62.0**	**66.6**
001002	7	853	31.3	68.8	0.1	2.0	0.6	28.3	0.2	*47.4*	49.4
001003	1	870	25.7	53.2	4.3	0.2	1.3	**41.0**	0.0	**59.0**	**64.0**
001003	2	1,080	20.4	53.2	1.9	1.4	0.1	**42.9**	0.6	**64.5**	**67.8**
001003	3	873	17.7	79.0	0.0	1.0	0.7	19.1	0.1	29.2	30.2
001003	4	813	8.4	77.5	3.9	1.1	0.4	16.6	0.5	27.1	32.7

County/ Tract	Block Group	Persons	Below Poverty Level (%)	White (%)	African American/ Black (%)	American Indian and Alaskan Native (%)	Asian or Other Pacific Islander (%)	Other Race (%)	Two or More Races (%)	Hispanic or Latino (All Races) (%)	Minorities (Racial Minorities Plus White Hispanics) (%)
001100	1	6	26.8	71.1	0.3	1.4	0.2	27.1	0.0	30.6	32.3
001100	3	980	21.6	71.4	1.1	0.2	1.1	26.1	0.0	35.0	37.2
001100	4	822	14.1	75.5	1.1	1.8	0.1	20.7	0.8	30.9	32.7
001100	5	612	11.3	82.0	1.4	2.0	0.3	14.0	0.5	21.9	25.0
Total New Mexico Block Groups			66								
State of Texas		20,851,820	15.4	71.0	11.7	0.9	3.0	13.0	0.4	32.0	47.6
Threshold for Environmental Justice Concerns			35.4	—	31.7	20.9	23.0	33.0	20.4	50.0/32.0	50.0
Andrews County											
950100	3	896	9.6	85.4	1.1	1.3	1.3	10.9	0.0	24.7	28.2
950100	4	591	9.9	84.3	0.5	1.9	2.9	10.5	0.0	19.8	25.9
950200	1	1,289	17.2	73.9	6.0	1.9	0.3	17.6	0.3	*37.5*	46.2
950200	2	923	19.8	68.8	2.7	0.9	1.1	26.4	0.1	*49.8*	**54.9**
950200	3	1,176	22.7	76.0	2.1	1.3	0.8	19.3	0.5	*37.6*	41.4
950200	6	692	7.2	75.4	2.2	1.0	0.3	21.1	0.0	*41.2*	43.5
950200	7	775	14.7	88.4	1.2	1.0	0.0	8.8	0.7	21.8	23.7
950200	8	752	0.0	94.7	0.4	0.7	2.0	2.1	0.1	5.1	8.8
950300	1	642	19.2	60.1	1.1	0.3	1.4	**37.1**	0.0	**70.6**	**72.7**
950300	2	593	22.4	72.2	3.7	1.0	0.0	22.9	0.2	**55.3**	**59.5**
950300	3	514	27.6	69.8	0.4	3.1	1.2	25.5	0.0	*48.6*	**53.1**
950300	4	914	15.7	69.4	2.0	2.2	0.3	25.7	0.4	**54.2**	**57.3**
950300	5	856	25.7	74.2	0.2	1.2	1.2	23.0	0.2	**61.1**	**63.7**
950400	6	420	9.8	86.9	0.5	0.2	1.7	10.7	0.0	*35.0*	37.9
950400	7	1,523	18.6	78.6	0.5	1.2	0.1	17.1	0.1	*40.4*	41.6

County/ Tract	Block Group	Persons	Below Poverty Level (%)	White (%)	African American/ Black (%)	American Indian and Alaskan Native (%)	Asian or Other Pacific Islander (%)	Other Race (%)	Two or More Races (%)	Hispanic or Latino (All Races) (%)	Minorities (Racial Minorities Plus White Hispanics) (%)
Ector County											
002200	1	622	10.0	82.3	0.2	1.2	0.0	16.1	0.3	*37.8*	39.3
002700	2	0	15.7	76.5	0.8	0.8	0.3	21.5	0.2	*40.1*	41.7
002700	4	690	17.1	64.4	1.8	1.3	0.2	31.7	0.6	**59.1**	**61.9**
003000	1	586	3.8	92.7	0.7	0.9	0.4	5.4	0.0	9.7	11.4
003000	2	38	2.8	88.8	0.3	1.7	0.3	8.9	0.0	14.8	16.7
Gaines County											
950100	1	246	25.2	80.6	0.5	1.4	0.0	16.8	0.7	*35.2*	36.5
950100	2	770	20.1	76.9	1.2	1.8	0.0	20.1	0.0	*42.5*	45.1
950100	3	778	21.3	68.1	7.5	0.1	0.1	23.5	0.6	**56.9**	**65.6**
950100	4	836	33.9	54.8	8.4	2.3	0.0	**34.3**	0.2	**69.6**	**79.4**
950100	5	584	20.6	78.3	2.4	0.0	0.0	18.7	0.7	*37.5*	41.4
950200	1	1,455	20.6	84.7	0.9	1.2	0.3	12.8	0.1	*32.1*	33.9
950200	2	2,470	17.7	83.4	1.2	1.1	0.0	14.0	0.3	23.4	24.9
950200	3	1,759	29.7	90.0	1.6	0.7	0.3	7.4	0.1	14.6	17.2
950300	1	818	24.5	70.8	5.5	1.7	0.7	21.1	0.1	**57.2**	**62.6**
950300	2	797	14.6	77.2	0.8	0.5	0.5	21.1	0.0	*45.7*	47.7
950300	3	1,243	16.2	91.1	1.5	0.5	0.6	6.4	0.1	18.7	21.8
950300	4	921	19.5	81.8	0.9	0.1	0.5	16.5	0.2	*40.8*	42.7
950300	5	1,281	21.1	78.0	3.1	2.7	1.1	15.1	0.0	*49.3*	**53.9**
Loving County											
950100	1	28	0.0	89.6	0.0	0.0	0.0	10.4	0.0	10.4	10.4
Terry County											
950100	3	41	15.8	82.1	0.0	2.2	0.0	15.8	0.0	*36.0*	36.2

County/ Tract	Block Group	Persons	Below Poverty Level (%)	White (%)	African American/ Black (%)	American Indian and Alaskan Native (%)	Asian or Other Pacific Islander (%)	Other Race (%)	Two or More Races (%)	Hispanic or Latino (All Races) (%)	Minorities (Racial Minorities Plus White Hispanics) (%)
Winkler County											
950200	1	720	17.0	80.4	1.3	0.3	0.0	17.2	0.8	*36.5*	38.1
950200	2	644	**37.4**	74.2	0.2	0.8	0.0	24.7	0.2	*41.1*	42.4
950200	3	846	11.8	69.4	5.1	1.1	0.0	24.3	0.1	*45.6*	**51.3**
950300	1	372	31.1	61.6	1.9	0.0	0.0	**34.9**	1.6	**75.8**	**79.0**
950300	2	673	14.0	76.2	2.8	0.5	0.9	19.2	0.5	*44.6*	48.7
950300	3	674	13.5	80.1	1.5	0.3	0.0	26.3	0.2	*41.8*	43.3
950300	4	994	15.5	71.9	3.0	1.3	0.1	23.6	0.0	*44.8*	49.2
950300	5	785	27.7	66.0	0.8	0.6	1.0	31.6	0.0	**62.7**	**64.3**
950400	1	589	9.5	78.5	1.1	0.6	0.0	19.1	0.7	*36.6*	38.0
950400	2	749	16.9	86.1	0.8	0.4	0.0	12.7	0.0	23.9	25.0
Yoakum County											
950100	1	128	14.4	84.2	1.7	0.0	0.0	14.1	0.0	*34.4*	36.1
950200	1	1,019	22.3	69.8	2.9	0.5	0.1	26.3	0.4	*41.7*	44.9
950200	2	1,138	20.6	67.0	1.1	1.3	0.4	30.0	0.2	**52.9**	**55.2**
950200	3	767	22.2	76.3	0.9	0.5	0.0	22.2	0.1	*40.7*	42.2
950200	4	1,220	19.1	59.3	1.1	1.3	0.2	**38.1**	0.1	**54.8**	**56.2**
950200	5	967	16.1	77.4	2.7	1.1	0.0	18.9	0.0	*34.2*	38.1
Total Texas Block Groups			51								
Grand Total			117								

[a] Minority block groups meeting standard Office of Nuclear Material Safety and Safeguards criteria are shown in bold. Additional block groups meeting special Hispanic/Latino criteria are shown in italics. Threshold criteria are shown in the table. Special Hispanic/Latino criteria are 42.1 percent for New Mexico, 32.0 percent for Texas.
Source: USCB, 2002a; USCB, 2002b.

G.2 References

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