APPENDIX E:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR PREPARING CYLINDERS FOR SHIPMENT OR LONG-TERM STORAGE

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The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
HEPA	high-efficiency particulate air (filter)
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
MCL	maximum contaminant level
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 μm or less
ROI	region of influence

Chemicals

CO	carbon monoxide
HC	hydrocarbons
HF	hydrogen fluoride
NaOH	sodium hydroxide
NO_x	nitrogen oxides
UF_6	uranium hexafluoride
UO_2F_2	uranyl fluoride
$UO_2(OH)_2$	uranyl hydroxide

UNITS OF MEASURE

Ci	curie(s)
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
gal	gallon(s)
gpm	gallon(s) per minute
GWh	gigawatt-hour(s)
ha	hectare(s)
kg	kilogram(s)
L	liter(s)
lb	pound(s)
μg	microgram(s)
μm	micrometer(s)
m	meter(s)
m^3	cubic meter(s)
min	minute(s)
mrem	millirem(s)
pCi	picocurie(s)
rem	roentgen equivalent man
s	second(s)
scf	standard cubic foot (feet)
ton(s)	short ton(s)
yd^3	cubic yard(s)
yr	year(s)

APPENDIX E:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR PREPARING CYLINDERS FOR SHIPMENT OR LONG-TERM STORAGE

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the cylinder preparation options considered in the PEIS. The discussion provides background information for these options, as well as a summary of the estimated environmental impacts associated with each option.

Cylinder Preparation Options

Cylinder preparation refers to the activities necessary to prepare depleted UF_6 cylinders for off-site transportation. Depleted UF_6 cylinders were designed, built, tested, and certified to meet U.S. Department of Transportation (DOT) requirements for shipment by truck and rail. However, after several decades in storage, some cylinders no longer meet these requirements. Two options for preparing these cylinders for shipment are considered in the PEIS.

Cylinder Overcontainers. Cylinders that do not meet DOT requirements could be placed inside protective metal "overcontainers" for shipment. These reusable overcontainers, which would be slightly larger than a cylinder, would be designed to meet all DOT requirements.

Cylinder Transfer. In this option, the depleted UF_6 in cylinders that do not meet DOT requirements would be transferred to new cylinders capable of being transported.

Note: For both options, cylinders that meet DOT shipment requirements would be shipped directly.

The term "cylinder preparation" refers to the activities necessary to prepare depleted UF_6 cylinders for off-site transportation. Under the PEIS alternative management strategies, transportation of depleted UF_6 cylinders was assumed to be required from the three current cylinder storage sites to either (1) a conversion facility or (2) a long-term storage site (for long-term storage of UF_6). UF_6 cylinders have been transported safely by truck and rail between DOE facilities, electric utilities, reactor fuel fabricators, and research nuclear reactors for about 40 years.

Depleted UF_6 cylinders were designed, built, tested, and certified to meet U.S. Department of Transportation (DOT) requirements for shipment by truck and rail. The DOT requirements, specified in Title 49 of the *Code of Federal Regulations* (CFR), are intended to maintain the safety of shipments during both routine and accident conditions. Cylinders meeting the DOT requirements could be loaded directly onto specially designed truck trailers or railcars for shipment. However, after several decades in storage, some cylinders no longer meet the DOT requirements. Two cylinder preparation options, which address different approaches that could be used to transport the depleted UF_6 stored in these cylinders, are considered in the PEIS. These two options, discussed in detail in Section E.2, are a cylinder overcontainer option and a cylinder transfer option.

It is unknown exactly how many of the depleted UF_6 cylinders currently do not meet the DOT transportation requirements. The potential problems with cylinders are related to three DOT requirements that must be satisfied before shipment: (1) cylinders must be filled to less than 62% of the maximum capacity (the fill-limit was reduced to 62% from 64% around 1987); (2) the pressure within cylinders must be less than atmospheric pressure; and (3) cylinders must be free of damage or defects, such as dents, and have a specified minimum wall thickness. Cylinders not meeting these requirements are referred to as overfilled, overpressurized, and substandard, respectively. Some cylinders may fail to meet more than one requirement.

The assessment of cylinder preparation options in the PEIS considers the environmental impacts of preparing the entire DOE-generated depleted UF_6 cylinder inventory for shipment over a 20-year period. Prior to shipment, each cylinder would be inspected to determine if it meets DOT requirements. This inspection would include a record review to determine if the cylinder is overfilled; a visual inspection for damage or defects; a pressure check to determine if the cylinder is overpressurized; and an ultrasonic wall thickness measurement (if necessary based on the visual inspection). If a cylinder passed the inspection, the appropriate documentation would be prepared, and the cylinder would be loaded directly for shipment. If a cylinder failed the inspection, it would be prepared using one of the two cylinder preparation options (see Section E.2).

If cylinder shipment was necessary under the alternative selected, this activity would occur at each site (e.g., cylinders might be shipped to a conversion facility or to a long-term storage facility, assuming that the site(s) selected for these facilities were not the current storage locations). Therefore, the assessment of cylinder preparation options in this PEIS was designed to address the entire range of potential cylinder preparation needs at each of the three sites, as follows:

- ***Paducah Site:*** The estimated number of cylinders not meeting DOT requirements at the Paducah site would range from 9,600 to 28,351 (the entire Paducah inventory of DOE-generated cylinders). On the basis of this estimate, there would be a need to provide overcontainer or cylinder transfer capacities for about 480 to 1,420 cylinders annually and, conversely, to prepare from 0 to 940 standard cylinders per year for shipment.

- ***Portsmouth Site:*** The estimated number of cylinders not meeting DOT requirements at the Portsmouth site would range from 2,600 to 13,388 (the entire Portsmouth inventory of DOE-generated cylinders). On the basis of this estimate, there would be a need to provide overcontainer or cylinder transfer capacities for about 130 to 670 cylinders annually and to prepare from 0 to 540 standard cylinders per year for shipment.

- ***K-25 Site:*** The estimated number of cylinders not meeting DOT requirements at the K-25 site would range from 2,342 to 4,683 (the entire K-25 inventory). On the basis of this estimate, there would be a need to provide overcontainer or cylinder transfer capacities for about 120 to 234 cylinders annually and to prepare from 0 to 120 standard cylinders per year for shipment.

The environmental impacts from the cylinder preparation options were evaluated on the basis of information provided in the engineering analysis report (Lawrence Livermore National Laboratory [LLNL] 1997), i.e., preconceptual design data for each option, including descriptions of facility layouts; resource requirements; estimated effluents, wastes, and emissions; and potential accident scenarios. In the engineering analysis report, estimates for cylinder transfer operations ranged in capacity from 320 to 1,600 cylinders processed per year; whereas overcontainer and standard cylinder operations were addressed on a site-specific basis for a reference case for each site (i.e., 960 cylinders/yr with overcontainers for the Paducah site, 260 cylinders/yr with overcontainers for the Portsmouth site, and 234 cylinders/yr with overcontainers for the K-25 site), with some information provided on scaling up or down from the reference case (LLNL 1997). Supporting data for the overcontainer and transfer facility analyses were derived by Folga (1996b) using information provided in the engineering analysis report (LLNL 1997).

For assessment purposes, it was assumed that all cylinders would require transportation. However, the actual need for transportation of cylinders would depend on site selection and other considerations to be addressed in the second tier of the *National Environmental Policy Act* (NEPA) process.

E.1 SUMMARY OF CYLINDER PREPARATION OPTION IMPACTS

This section provides a summary of the potential environmental impacts associated with the cylinder preparation options. Additional discussion and details related to the assessment methodologies and results for individual areas of impact are provided in Section E.3.

Potential environmental impacts are summarized in Tables E.1, E.2, and E.3 for the Paducah, Portsmouth, and K-25 sites, respectively. Ranges of impacts are presented for the over-container option, the cylinder transfer option, and the preparation of standard cylinders (which is required for either option). Based on the information in Tables E.1 through E.3 and Section E.3, the following general conclusions may be drawn:

- For the cylinder overcontainer option and preparation of standard cylinders, impacts during normal operations would be small and limited to involved workers. No impacts to the off-site public or the environment would occur because no releases would be expected and no construction activities would be required.

TABLE E.1 Summary of Cylinder Preparation Impacts for the Paducah Site

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 170 – 510 person-rem Total number of LCFs: 0.07 – 0.2 LCF	**Involved Workers:** Total collective dose: 610 – 1,000 person-rem Total number of LCFs: 0.2 – 0.4 LCF	**Involved Workers:** Total collective dose: 0 – 220 person-rem Total number of LCFs: 0 – 0.09 LCF
Noninvolved Workers: No impacts	**Noninvolved Workers:** Annual dose to MEI: $1.9 \times 10^{-6} - 4.9 \times 10^{-6}$ mrem/yr Annual cancer risk to MEI: $8 \times 10^{-13} - 2 \times 10^{-12}$ per year Total collective dose: $5.1 \times 10^{-5} - 1.3 \times 10^{-4}$ person-rem Total number of LCFs: $2 \times 10^{-8} - 5 \times 10^{-8}$ LCF	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** Annual dose to MEI: $6.8 \times 10^{-6} - 1.7 \times 10^{-5}$ mrem/yr Annual cancer risk to MEI: $3 \times 10^{-12} - 9 \times 10^{-12}$ per year Total collective dose to population within 50 miles: $1.1 \times 10^{-3} - 2.9 \times 10^{-3}$ person-rem Total number of LCFs in population within 50 miles: $6 \times 10^{-7} - 1 \times 10^{-6}$ LCF	**General Public:** No impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE E.1 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem
Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}
Collective dose: 15 person-rem	Collective dose: 15 person-rem	Collective dose: 15 person-rem
Number of LCFs: 6×10^{-3}	Number of LCFs: 6×10^{-3}	Number of LCFs: 6×10^{-3}
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem
Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}
Collective dose to population within 50 miles: 28 person-rem	Collective dose to population within 50 miles: 28 person-rem	Collective dose to population within 50 miles: 28 person-rem
Number of LCFs in population within 50 miles: 0.01 LCF	Number of LCFs in population within 50 miles: 0.01 LCF	Number of LCFs in population within 50 miles: 0.01 LCF
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 910 persons	Number of persons with potential for adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 450 persons	Number of persons with potential for adverse effects: 910 persons
Number of persons with potential for irreversible adverse effects: 300 persons	Number of persons with potential for irreversible adverse effects: 330 persons	Number of persons with potential for irreversible adverse effects: 300 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 1,900 persons	Number of persons with potential for adverse effects: 2,500 persons	Number of persons with potential for adverse effects: 1,900 persons
Number of persons with potential for irreversible adverse effects: 1 person	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 1 person

TABLE E.1 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Human Health — Accidents: Physical Hazards	
Operations: **All Workers:** Less than 1 (0.029 – 0.087) fatality, approximately 39 – 115 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.31 – 0.34) fatality, approximately 210 – 250 injuries	**Operations:** **All Workers:** Less than 1 (0 – 0.043) fatality, approximately 0 – 87 injuries
	Air Quality	
Construction: Not applicable	**Construction:** 24-hour PM_{10} impacts potentially as large as 62% of standard. Concentrations of other criteria pollutants all below 15% of respective standards.	**Construction:** Not applicable
Operations: Concentrations of all criteria pollutants below 0.08% of respective standards.	**Operations:** Concentrations of all criteria pollutants below 0.08% of respective standards.	**Operations:** Concentrations of all criteria pollutants below 0.03% of respective standards.
	Water	
Construction: Not applicable	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Not applicable
Operations: None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards	**Operations:** None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards	**Operations:** None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards
	Soil	
Construction: Not applicable	**Construction:** Negligible, but temporary, impacts	**Construction:** Not applicable
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Preoperations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Preoperations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.
Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.

TABLE E.1 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Ecology	
Construction: Not applicable	**Construction:** Potentially moderate impacts to vegetation, wildlife, and wetlands	**Construction:** Not applicable
Operations: Negligible impacts	**Operations:** Negligible impacts	**Operations:** No impacts
	Waste Management	
No impacts on regional or national waste management operations	No impacts on regional or national waste management operations	No impacts on regional or national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected
	Land Use	
No impacts	Use of approximately 21 acres; negligible impacts	No impacts
	Cultural Resources	
Construction: No impacts	**Construction:** Cannot be determined	**Construction:** No impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts

[a] Problem cylinders are cylinders not meeting DOT transportation requirements, either because they are (1) overfilled, (2) overpressurized, or (3) damaged or substandard with respect to wall thickness.

[b] These impacts must be added to those for either of the two options for preparation of problem cylinders.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 μm or less; ROI = region of influence.

TABLE E.2 Summary of Cylinder Preparation Impacts for the Portsmouth Site

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 47 – 240 person-rem	**Involved Workers:** Total collective dose: 410 – 690 person-rem	**Involved Workers:** Total collective dose: 0 – 120 person-rem
Total number of LCFs: 0.02 – 0.1 LCF	Total number of LCFs: 0.2 – 0.3 LCF	Total number of LCFs: 0 – 0.05 LCF
Noninvolved Workers: No impacts	**Noninvolved Workers:** Annual dose to MEI: $1.9 \times 10^{-6} - 7.9 \times 10^{-6}$ mrem/yr	**Noninvolved Workers:** No impacts
	Annual cancer risk to MEI: $7 \times 10^{-13} - 3 \times 10^{-12}$ per year	
	Total collective dose: $2.6 \times 10^{-5} - 1.1 \times 10^{-4}$ person-rem	
	Total number of LCFs: $1 \times 10^{-8} - 4 \times 10^{-8}$ LCF	
General Public: No impacts	**General Public:** Annual dose to MEI: $3.3 \times 10^{-5} - 4.4 \times 10^{-5}$ mrem/yr	**General Public:** No impacts
	Annual cancer risk to MEI: 2×10^{-11} per year	
	Total collective dose to population within 50 miles: $3.1 \times 10^{-4} - 1.3 \times 10^{-3}$ person-rem	
	Total number of LCFs in population within 50 miles: $2 \times 10^{-7} - 7 \times 10^{-7}$ LCF	
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE E.2 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		
Cylinder Overcontainer Operations	Cylinder Transfer Operations	Impacts from Preparation of Standard Cylinders[b]
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Dose to MEI: 0.02 rem	Dose to MEI: 0.02 rem	Dose to MEI: 0.02 rem
Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}
Collective dose: 16 person-rem	Collective dose: 16 person-rem	Collective dose: 16 person-rem
Number of LCFs: 6×10^{-3}	Number of LCFs: 6×10^{-3}	Number of LCFs: 6×10^{-3}
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Dose to MEI: 0.015 rem	Dose to MEI: 0.015 rem	Dose to MEI: 0.015 rem
Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}
Collective dose to population within 50 miles: 32 person-rem	Collective dose to population within 50 miles: 32 person-rem	Collective dose to population within 50 miles: 32 person-rem
Number of LCFs in population within 50 miles: 0.02 LCF	Number of LCFs in population within 50 miles: 0.02 LCF	Number of LCFs in population within 50 miles: 0.02 LCF
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 1,000 persons	Number of persons with potential for adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 520 persons	Number of persons with potential for adverse effects: 1,000 persons
Number of persons with potential for irreversible adverse effects: 110 persons	Number of persons with potential for irreversible adverse effects: 440 persons	Number of persons with potential for irreversible adverse effects: 110 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 650 persons	Number of persons with potential for adverse effects: 580 persons	Number of persons with potential for adverse effects: 650 persons
Number of persons with potential for irreversible adverse effects: 1 person	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 1 person

TABLE E.2 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		
Cylinder Overcontainer Operations	**Cylinder Transfer Operations**	**Impacts from Preparation of Standard Cylinders[b]**
	Human Health — Accidents: Physical Hazards	
Operations: **All Workers:** Less than 1 (0.007 – 0.041) worker fatality, approximately 10 – 54 worker injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.22 – 0.31) worker fatality, approximately 110 – 240 worker injuries	**Operations:** **All Workers:** Less than 1 (0 – 0.025) worker fatality, approximately 0 – 33 worker injuries
	Air Quality	
Construction: Not applicable	**Construction:** 24-hour PM_{10} impacts potentially as large as 36% of standard. Concentrations of other criteria pollutants all below 7% of respective standards.	**Construction:** Not applicable
Operations: Concentrations of all criteria pollutants below 0.02% of respective standards.	**Operations:** Concentrations of all criteria pollutants below 0.04% of respective standards.	**Operations:** Concentrations of all criteria pollutants below 0.01% of respective standards.
	Water	
Construction: Not applicable	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Not applicable
Operations: None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards	**Operations:** None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards	**Operations:** None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards
	Soil	
Construction: Not applicable	**Construction:** Negligible, but temporary, impacts	**Construction:** Not applicable
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Preoperations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Preoperations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.
Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.

TABLE E.2 (Cont.)

Impacts from Preparation of Problem Cylinders[a]: Cylinder Overcontainer Operations	Impacts from Preparation of Problem Cylinders[a]: Cylinder Transfer Operations	Impacts from Preparation of Standard Cylinders[b]
	Ecology	
Construction: Not applicable	**Construction:** Potentially moderate impacts to vegetation, wildlife, and wetlands	**Construction:** Not applicable
Operations: Negligible impacts	**Operations:** Negligible impacts	**Operations:** No impacts
	Waste Management	
No impacts on regional or national waste management operations	No impacts on regional or national waste management operations	No impacts on regional or national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale
	Land Use	
No impacts	Use of approximately 14 acres; negligible impacts	No impacts
	Cultural Resources	
Construction: No impacts	**Construction:** Cannot be determined	**Construction:** No impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts

[a] Problem cylinders are cylinders not meeting DOT transportation requirements, either because they are (1) overfilled, (2) overpressurized, or (3) damaged or substandard with respect to wall thickness.

[b] These impacts must be added to those for either of the two options for preparation of problem cylinders.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 μm or less; ROI = region of influence.

TABLE E.3 Summary of Cylinder-Preparation Impacts for the K-25 Site

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 42 – 85 person-rem Total number of LCFs: 0.02 – 0.03 LCF	**Involved Workers:** Total collective dose: 410 – 480 person-rem Total number of LCFs: 0.2 LCF	**Involved Workers:** Total collective dose: 0 – 27 person-rem Total number of LCFs: 0 – 0.01 LCF
Noninvolved Workers: No impacts	**Noninvolved Workers:** Annual dose to MEI: $2.0 \times 10^{-6} - 3.7 \times 10^{-6}$ mrem/yr Annual cancer risk to MEI: $8 \times 10^{-13} - 2 \times 10^{-12}$ per year Total collective dose: $3.1 \times 10^{-5} - 5.6 \times 10^{-5}$ person-rem Total number of LCFs: $1 \times 10^{-8} - 2 \times 10^{-8}$ LCF	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** Annual dose to MEI: $2.4 \times 10^{-5} - 2.9 \times 10^{-5}$ mrem/yr Annual cancer risk to MEI: 1×10^{-11} per year Total collective dose to population within 50 miles: $9.8 \times 10^{-4} - 1.8 \times 10^{-3}$ person-rem Total number of LCFs in population within 50 miles: $5 \times 10^{-7} - 9 \times 10^{-7}$ LCF	**General Public:** No impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE E.3 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		
Cylinder Overcontainer Operations	Cylinder Transfer Operations	Impacts from Preparation of Standard Cylinders[b]
Human Health – Accidents: Radiological		
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem
Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}
Collective dose: 16 person-rem	Collective dose: 16 person-rem	Collective dose: 16 person-rem
Number of LCFs: 6×10^{-3}	Number of LCFs: 6×10^{-3}	Number of LCFs: 6×10^{-3}
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem
Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}
Collective dose to population within 50 miles: 63 person-rem	Collective dose to population within 50 miles: 63 person-rem	Collective dose to population within 50 miles: 63 person-rem
Number of LCFs in population within 50 miles: 0.03 LCF	Number of LCFs in population within 50 miles: 0.03 LCF	Number of LCFs in population within 50 miles: 0.03 LCF
Human Health – Accidents: Chemical		
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 770 persons	Number of persons with potential for adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 500 persons	Number of persons with potential for adverse effects: 770 persons
Number of persons with potential for irreversible adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 140 persons	Number of persons with potential for irreversible adverse effects: 190 persons	Number of persons with potential for irreversible adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 140 persons

TABLE E.3 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		
Cylinder Overcontainer Operations	Cylinder Transfer Operations	Impacts from Preparation of Standard Cylinders[b]
	Human Health – Accidents: Chemical (Cont.)	
General Public: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 550 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 980 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 550 persons Number of persons with potential for irreversible adverse effects: 0 persons
	Human Health — Accidents: Physical Hazards	
Operations: **All Workers:** Less than 1 (0.007 – 0.014) worker fatality, approximately 9 – 18 worker injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.17 – 0.21) worker fatality, approximately 94 – 140 worker injuries	**Operations:** **All Workers:** Less than 1 (0 – 0.006) worker fatality, approximately 0 - 7 worker injuries
	Air Quality	
Construction: Not applicable	**Construction:** 24-hour PM_{10} impacts potentially as large as 87% of standard. Concentrations of other criteria pollutants all below 11% of respective standards.	**Construction:** Not applicable
Operations: Concentrations of all criteria pollutants below 0.01% of respective standards.	**Operations:** Concentrations of all criteria pollutants below 0.07% of respective standards.	**Operations:** Concentrations of all criteria pollutants below 0.004% of respective standards.
	Water	
Construction: Not applicable	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Not applicable
Operations: None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards	**Operations:** None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards	**Operations:** None to negligible impacts for runoff, floodplains, recharge, and depth to groundwater; estimated surface water and groundwater concentrations would not exceed drinking water standards
	Soil	
Construction: Not applicable	**Construction:** Negligible, but temporary, impacts	**Construction:** Not applicable
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts

TABLE E.3 (Cont.)

Impacts from Preparation of Problem Cylinders[a]		Impacts from Preparation of Standard Cylinders[b]
Cylinder Overcontainer Operations	Cylinder Transfer Operations	
	Socioeconomics	
Preoperations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances. **Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances. **Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Preoperations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances. **Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.
	Ecology	
Construction: Not applicable **Operations:** Negligible impacts	**Construction:** Potentially moderate impacts to vegetation, wildlife, and wetlands **Operations:** Negligible impacts	**Construction:** Not applicable **Operations:** No impacts
	Waste Management	
No impacts on regional or national waste management operations	No impacts on regional or national waste management operations	No impacts on regional or national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale
	Land Use	
No impacts	Use of approximately 12 acres; negligible impacts	No impacts
	Cultural Resources	
Construction: No impacts **Operations:** No impacts	**Construction:** Cannot be determined **Operations:** No impacts	**Construction:** No impacts **Operations:** No impacts

[a] Problem cylinders are cylinders not meeting DOT transportation requirements, either because they are (1) overfilled, (2) over-pressurized, or (3) damaged or substandard with respect to wall thickness.

[b] These impacts must be added to those for either of the two options for preparation of problem cylinders.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 μm or less; ROI = region of influence.

- For the cylinder transfer option, impacts during construction and normal operations would generally be small and limited primarily to involved workers. Some small off-site releases of hazardous and nonhazardous materials would occur, although these would have negligible impacts on the off-site public and environment. Construction activities could temporarily impact air quality, but concentrations of criteria pollutants would all be within standards.

- For both options, there is a potential for low-probability accidents (UF_6 cylinders engulfed in a fire) that could have large consequences. The accident impacts would be limited primarily to workers, but off-site impacts are possible.

E.2 DESCRIPTION OF OPTIONS

This section provides a brief summary of the cylinder preparation options considered in the assessment of impacts. The information is based on preconceptual design data provided in the engineering analysis report (LLNL 1997). The engineering analysis report includes much more detailed information, including descriptions of facility layouts, resource requirements, estimates of effluents, wastes, and emissions, and descriptions of potential accident scenarios.

Prior to shipment, each cylinder would be inspected to determine if it meets DOT requirements. This inspection would include a record review to determine if the cylinder is overfilled; a visual inspection for damage or defects; a pressure check to determine if the cylinder is overpressurized; and an ultrasonic wall thickness measurement (if necessary based on the visual inspection). If a cylinder passed the inspection, the appropriate documentation would be prepared, and the cylinder would be loaded directly for shipment.

The preparation of standard cylinders for shipment (cylinders that meet DOT requirements) would include inspection activities, unstacking, on-site transfer, and loading onto a truck trailer or railcar. The cylinders would be secured using the appropriate tiedowns, and the shipment would be labeled in accordance with DOT requirements. Handling and support equipment and procedures for on-site movement and loading the cylinders would be of the same type currently used for cylinder management activities at the three storage sites.

E.2.1 Cylinder Overcontainers

Cylinder overcontainers are one option for transporting cylinders that do not meet DOT requirements. An overcontainer is simply a container into which a cylinder would be placed for shipment. The metal overcontainer would be designed, tested, and certified to meet all DOT shipping requirements. The overcontainer would be suitable to contain, transport, and store the cylinder contents regardless of cylinder condition. In addition, the overcontainers could be designed as pressure vessels, enabling the withdrawal of the depleted UF_6 from the cylinder in an autoclave (a device used to heat cylinders using hot air).

The type of overcontainer evaluated in the PEIS, shown in Figure E.1, is a horizontal "clamshell" vessel (LLNL 1997). For transportation, a cylinder not meeting DOT requirements would be placed into an overcontainer already on a truck trailer or railcar. The overcontainer would be closed, secured, and the shipment would be labeled in accordance with DOT requirements. The handling and support equipment for on-site movement and loading the cylinder into the

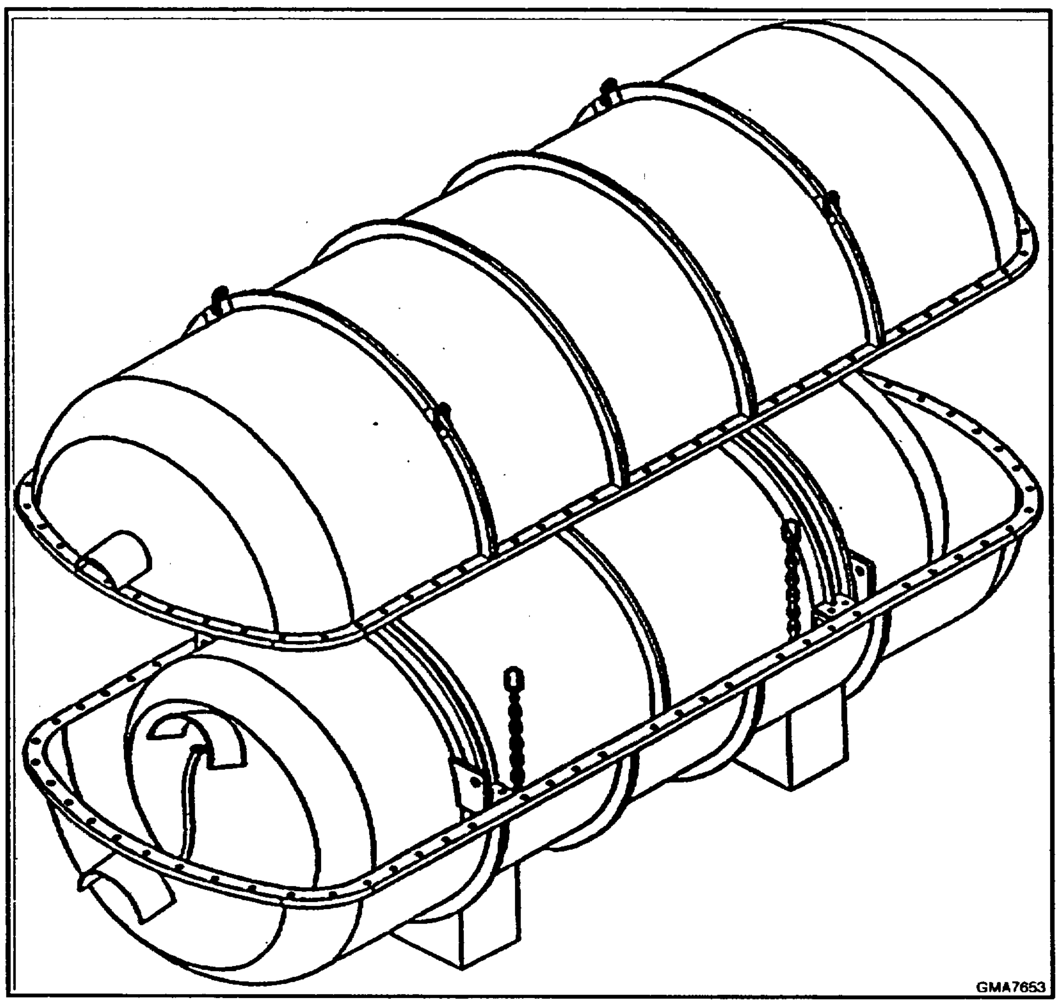

FIGURE E.1 Horizontal "Clamshell" Overcontainer for Transportation of Cylinders Not Meeting DOT Requirements (Source: LLNL 1997)

overcontainer would be of the same type currently used for cylinder management activities at the three DOE sites. The overcontainers could be reused following shipment. The overcontainer option would not require the construction of new facilities.

E.2.2 Cylinder Transfer

A second option for transporting cylinders that do not meet DOT requirements would be to transfer the depleted UF_6 from substandard cylinders to new cylinders that meet all DOT requirements. This option would require the construction of a new facility. A representative transfer facility is shown in Figure E.2. The transfer facility would be a stand-alone facility capable of receiving cylinders, storing a small number of cylinders, and transferring the contents to new cylinders. The transfer of depleted UF_6 would take place in a process building by placing substandard cylinders into autoclaves. The autoclaves would be used to heat the contents of the cylinder (using hot air), forming UF_6 gas which then would be piped to a new cylinder. The new cylinders could be shipped by placing them directly on appropriate trucks or railcars. The empty cylinders would be cleaned and treated with other scrap metals. (See Appendix F for details on the treatment of empty cylinders.)

E.3 IMPACTS OF OPTIONS

This section provides a summary of the potential environmental impacts associated with the cylinder preparation options, including impacts from construction (of a cylinder transfer facility), and during operations. Information related to the assessment methodologies for each area of impact is provided in Appendix C.

The environmental impacts from the cylinder preparation options were evaluated on the basis of the information described in the engineering analysis report (LLNL 1997) and Folga (1996a). The following general assumptions apply to the assessment of impacts:

- The assessment considers preparation of cylinders that meet DOT requirements (standard cylinders), as well as those cylinders that do not meet the requirements.

- Evaluation of standard cylinder preparation and the cylinder overcontainer option includes only an operational phase — no construction activities would be required. Additionally, these options would not generate emissions of uranium compounds or hydrogen fluoride (HF) during normal operations.

- The evaluation of the cylinder transfer option includes construction of a facility in addition to operations. The operation of a cylinder transfer facility would involve small releases of uranium compounds and HF as air and water effluents during normal operations.

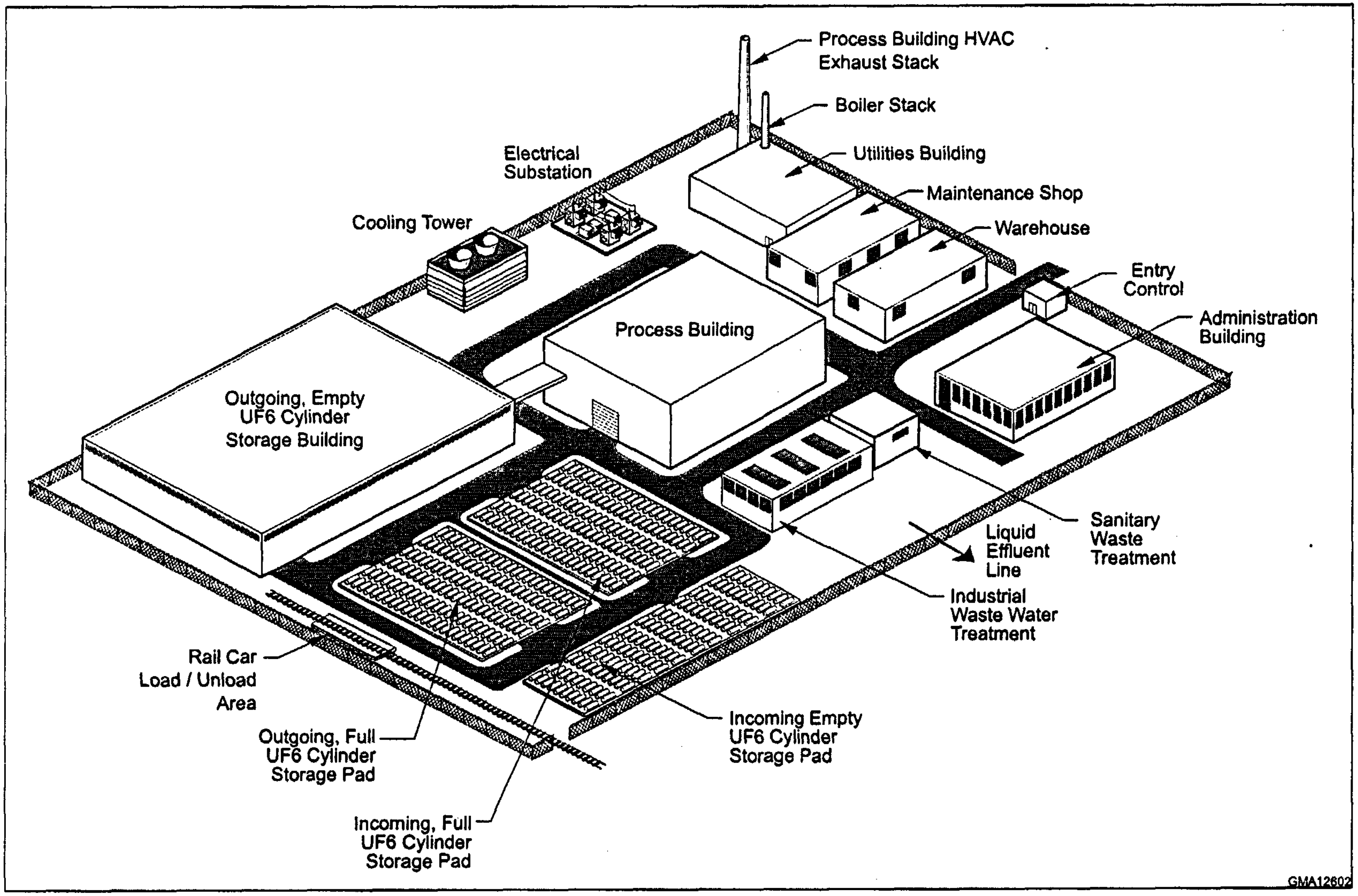

FIGURE E.2 Representative Layout of a Transfer Facility Site (Source: LLNL 1997)

- Impacts were evaluated separately for the three current storage sites, assuming a range in annual processing requirements at each site, because the actual number of cylinders that would not meet DOT requirements at the time of shipment cannot be determined. The ranges of problem cylinders at each site are discussed in the opening section of this appendix. The remaining cylinders were assumed to be standard cylinders that could be shipped directly.

- Cylinder preparation activities would take place over a 20-year period, from 2009 through 2028, for all alternatives except the no action alternative, which does not involve cylinder preparation.

E.3.1 Human Health — Normal Operations

E.3.1.1 Radiological Impacts

Potential radiological impacts for the cylinder preparation options were assessed for involved workers, noninvolved workers, and the general public. Detailed discussions of the methodologies used in the radiological impact analyses are provided in Appendix C and Cheng et al. (1997).

Impacts to involved workers would result primarily from external radiation and would depend only on the number of cylinders handled. The estimated collective doses to involved workers are presented in Figures E.3, E.4, and E.5 for the overcontainer option, cylinder transfer option, and preparation of standard cylinders, respectively. The collective dose is presented as a solid line, with three dashed lines above or below showing the corresponding segments representative for the three cylinder storage sites. Because no airborne or waterborne releases of uranium would be generated for the overcontainer option and preparation of standard cylinders, no radiological impacts would be expected to noninvolved workers or members of the general public. Impacts to these two receptors for the cylinder transfer option are presented in Figures E.6 through E.9. The ranges of impacts for the three cylinder storage sites are different because of the different numbers of cylinder handled and different site characteristics; the ranges are presented by three separate solid lines in the figures.

In general, impacts for the overcontainer option would be less than those for the cylinder transfer option. The average doses to involved workers for all cylinder preparation activities would be less than 660 mrem/yr, which is less than the regulatory limit of 5,000 mrem/yr (10 CFR Part 835). Exposure of noninvolved workers and members of the general public would be extremely small, less than 3.0×10^{-5} mrem/yr.

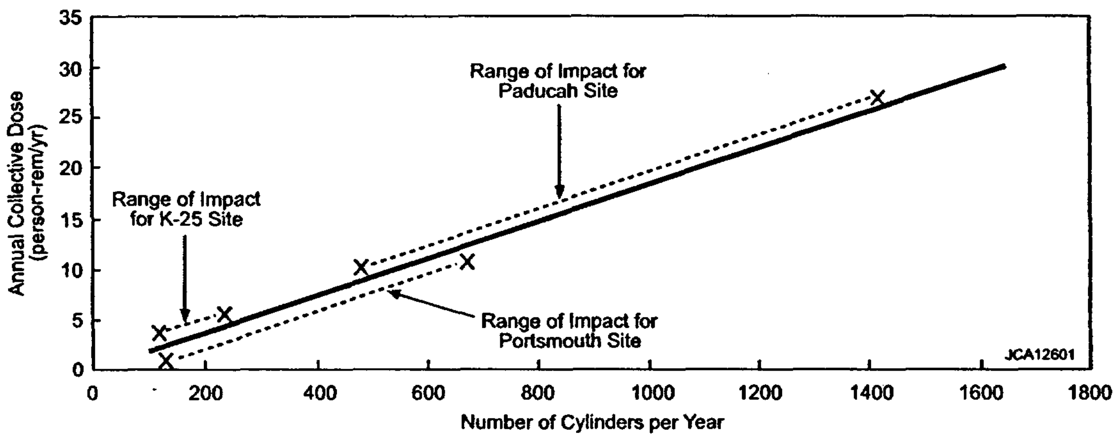

FIGURE E.3 Annual Collective Dose to Involved Workers from Preparing Problem Cylinders for Shipment Using Overcontainers

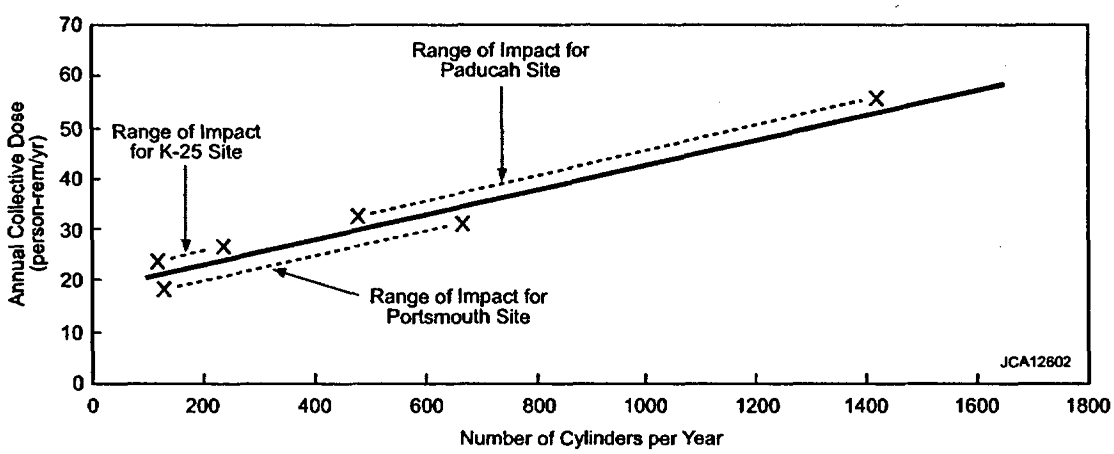

FIGURE E.4 Estimated Annual Collective Dose to Involved Workers from Preparing Problem Cylinders for Shipment Using the Cylinder Transfer Technology

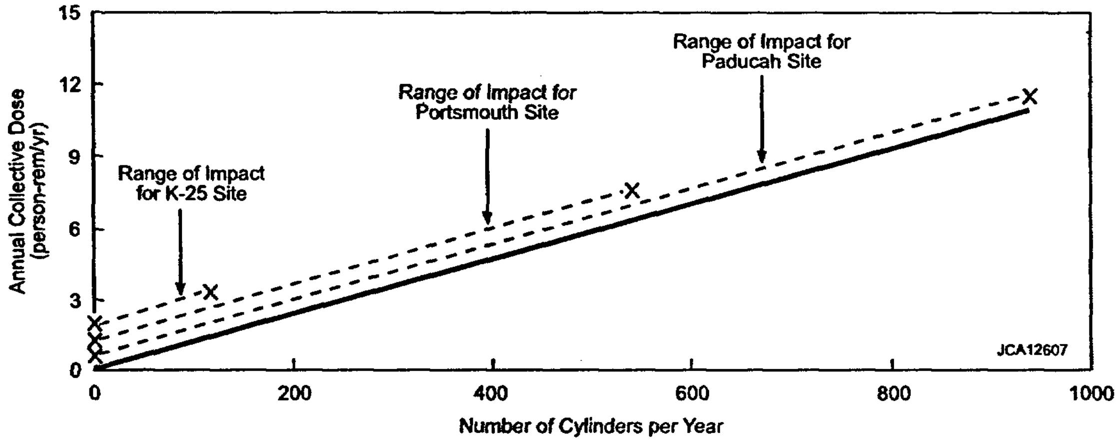

FIGURE E.5 Annual Collective Dose to Involved Workers from Preparing Standard Cylinders for Shipment

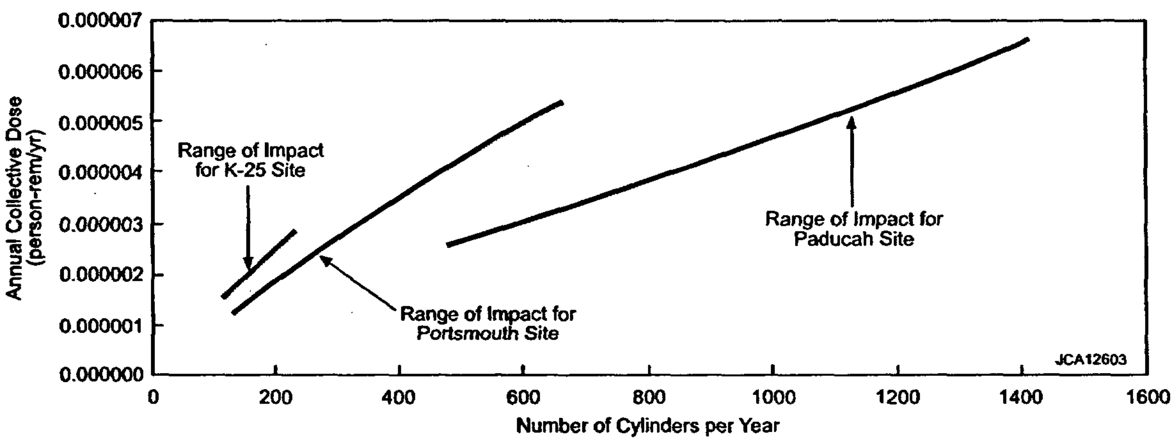

FIGURE E.6 Estimated Annual Collective Dose to Noninvolved Workers from Preparing Problem Cylinders for Shipment Using the Cylinder Transfer Technology (population size of noninvolved workers: about 2,000 at Paducah; 2,700 at Portsmouth; and 3,500 at the K-25 Site)

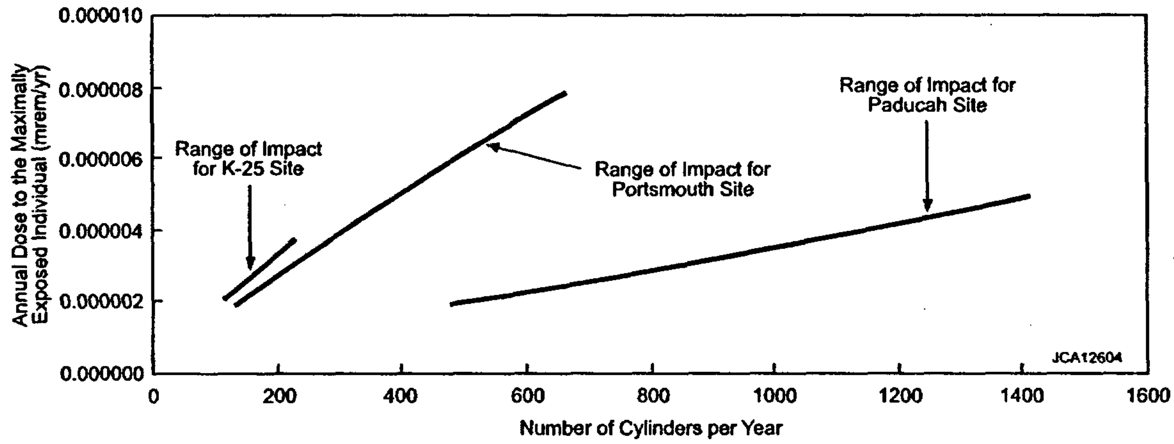

FIGURE E.7 Estimated Annual Dose to the Noninvolved Worker MEI from Preparing Problem Cylinders for Shipment Using the Cylinder Transfer Technology

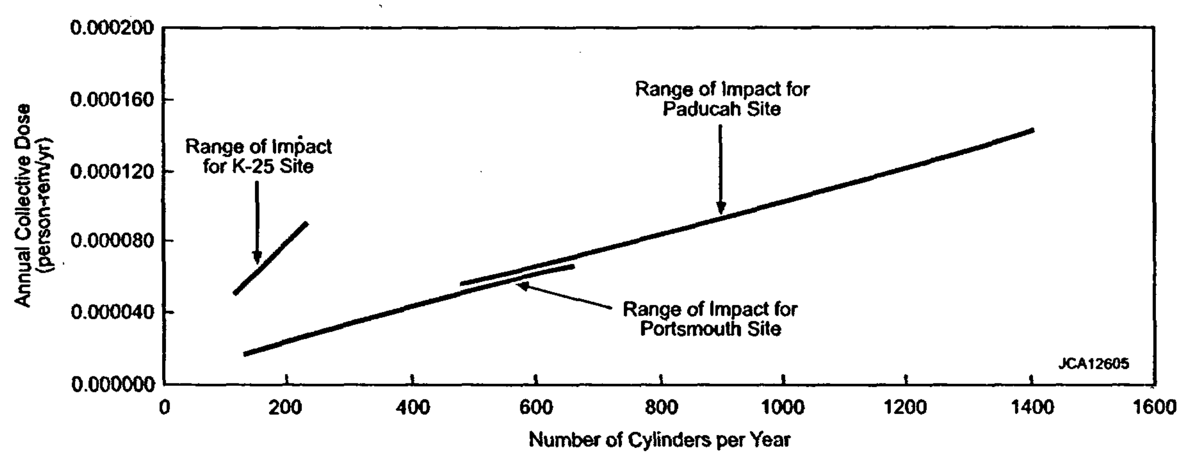

FIGURE E.8 Estimated Annual Collective Dose to the General Public from Preparing Problem Cylinders for Shipment Using the Cylinder Transfer Technology (exposure to airborne emissions; population size of general public: about 500,000 at Paducah; 605,000 at Portsmouth; and 877,000 at the K-25 Site)

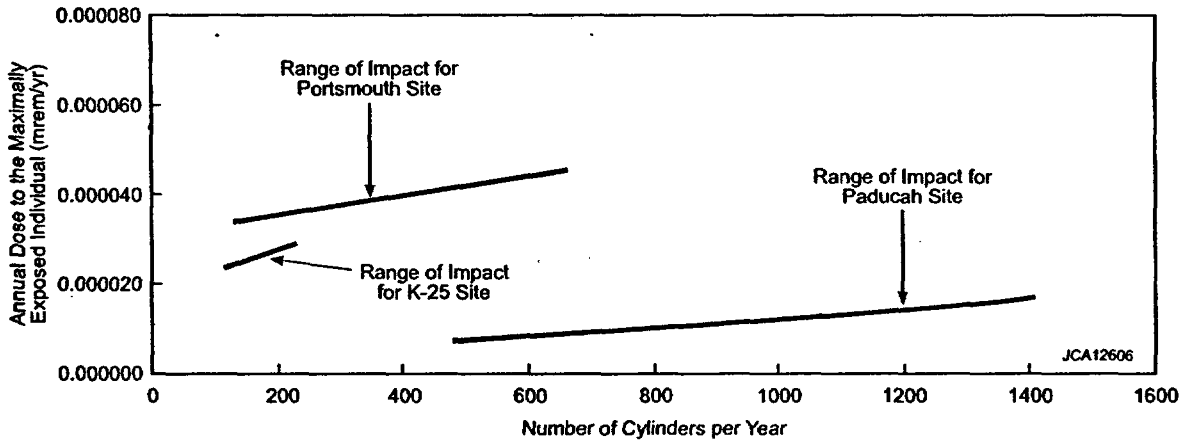

FIGURE E.9 Estimated Annual Dose to the General Public MEI from Preparing Problem Cylinders for Shipment Using the Cylinder Transfer Technology (exposures would result from airborne emissions and discharge of wastewater)

E.3.1.1.1 Overcontainer Option

Potential external radiation exposures of involved workers would occur from preshipment inspection, testing, and surveying of cylinders; unstacking and retrieving cylinders; on-site transportation of cylinders by straddle buggy; loading cylinders into overcontainers placed on trucks or railcars; and packaging cylinders. The annual collective dose to involved workers was estimated to be approximately 2.1 to 4.3 person-rem/yr for about 4 to 8 workers at the K-25 site, 2.4 to 12.2 person-rem/yr for about 5 to 22 workers at the Portsmouth site, and 8.7 to 26 person-rem/yr for about 16 to 47 workers at the Paducah site. Assuming that the workers would work 5 hours per day with an availability factor of 75%, i.e., 3.75 hours per day for cylinder preparation activities (Folga 1996c), the average individual involved worker dose would be approximately 540 mrem/yr. The corresponding average cancer risk would be approximately 0.0002 per year (i.e., an individual's chance of developing a latent fatal cancer would be less than 1 in 5,000 per year).

E.3.1.1.2 Cylinder Transfer Option

The collective dose to involved workers would range from 20 to 24 person-rem/yr for approximately 31 to 42 workers at the K-25 site, 21 to 34 person-rem/yr for approximately 32 to 62 workers at the Portsmouth site, and 30 to 52 person-rem/yr for approximately 52 to 94 workers at the Paducah site. The average individual dose to involved workers would be less than 660 mrem/yr, corresponding to a risk of latent cancer fatality (LCF) of 3×10^{-4} per year (one chance in 3,300 per year).

Radiation doses to noninvolved workers vary from site to site depending on the processing rate of cylinders, site-specific meteorological conditions, and distribution and population of the on-site workers (for collective doses). The estimated radiation dose to the maximally exposed individual (MEI) would be extremely small, less than 8×10^{-6} mrem/yr, due to the small airborne emission rates of uranium. Impacts to the off-site public would also depend on the factors discussed for noninvolved workers, but instead of the distribution and population of the on-site workers, the impacts would be determined by the distribution and population of the off-site public (for collective dose).

The radiation dose to the MEI of the off-site public would be greater than that for the MEI of the noninvolved workers because of the additional exposure from drinking surface water. The radiation dose from drinking surface water would be greater than that from airborne emissions. As a result, the MEI dose for the Paducah site would be less than the doses for the Portsmouth and K-25 sites because surface water around the Paducah site would have the largest dilution capability. The radiation doses to the off-site public MEI from normal operations of the cylinder transfer facility were estimated to be less than 4.4×10^{-5} mrem/yr for all three cylinder storage sites, which is extremely small compared with the regulatory limit of 100 mrem/yr.

E.3.1.1.3 Preparation of Standard Cylinders

The collective radiation exposures to involved workers were estimated to range from 0 to 1.4 person-rem/yr for the K-25 site. The lower range results from the assumption that all the cylinders at the K-25 sites would be problem cylinders. A maximum of four workers would be required for the preparation activities. Radiation doses to involved workers at the Portsmouth site would range from 0 to 6.2 person-rem/yr, with a maximum requirement of 11 workers. At the Paducah site, the collective doses were estimated to range from 0 to 11 person-rem/yr, with a maximum requirement of 18 workers. The average individual dose to involved workers was estimated to be less than 600 mrem/yr for all three cylinder storage sites.

E.3.1.2 Chemical Impacts

The only potential chemical impacts that could be associated with cylinder preparation options would be from exposure to emissions from a cylinder transfer facility; no impacts during normal operations would be expected for the cylinder overcontainer option or preparation of standard cylinders because no releases would occur. Risks from normal operations were quantified on the basis of calculated hazard indices. Information on the exposure assumptions, health effects assumptions, reference doses, and calculational methods used in the chemical impact analysis is provided in Appendix C and Cheng et al. (1997).

During cylinder transfer operations, very small quantities of uranyl fluoride (UO_2F_2) effluent would be discharged into the air and surface water. Estimates of the hazardous chemical human health impacts resulting from cylinder transfer operations were calculated for the range of cylinders that might require processing at each of the three storage sites (i.e., up to 1,420 annually at Paducah, 670 annually at Portsmouth, and 234 annually at K-25). Inhalation of HF was not included in the hazard index calculations because HF emissions from the cylinder transfer facility would be hundreds of times lower than HF emissions from conversion facilities (see Appendix F), for which no chemical impacts were predicted.

No impacts to noninvolved workers or the general public would be expected from normal transfer facility operations. The maximum (high case) hazard indices for chemical impacts to the noninvolved worker MEI working at the cylinder transfer facility would be less than or equal to 3.2×10^{-8}, 3.0×10^{-8}, and 1.1×10^{-8} at the Paducah, Portsmouth, and K-25 sites, respectively. These values are considerably below the threshold for adverse effects (i.e., the ratio of intake to reference dose is much less than 1). The maximum (high case) hazard indices for chemical impacts to the general public MEI would be less than or equal to 2.8×10^{-6}, 6.1×10^{-6}, and 3.6×10^{-6} at the Paducah, Portsmouth, and K-25 sites, respectively; these values are also considerably below the threshold for adverse effects.

E.3.2 Human Health — Accident Conditions

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents has been presented in the engineering analysis report (LLNL 1997). These accidents are listed in Table E.4. The results for the radiological and chemical health impacts of the maximum-consequence accident in each frequency category are presented in Sections E.3.2.1 and E.3.2.2. The bounding accidents are the same for both the cylinder overcontainer option and the cylinder transfer option. Results for all accidents listed in Table E.4 are presented in Policastro et al. (1997). Detailed descriptions of the methodology and assumptions used in these calculations are also provided in Appendix C and Policastro et al. (1997).

E.3.2.1 Radiological Impacts

Table E.5 lists the radiological doses to various receptors for the accidents that give the highest dose from each frequency category. The LCF risks for these accidents are given in Table E.6. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions were considered for each cylinder preparation option (see Appendix C). The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely category have a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

TABLE E.4 Accidents Considered for the Cylinder Preparation Options

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Cylinder Overcontainers					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, three full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Incredible Accidents (frequency: less than 1 time in 1 million years)					
Small plane crash, two full 48G cylinders[b]	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Cylinder Transfer					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Cylinder valve shear	A single UF_6 cylinder is mishandled, etc., resulting in shearing of the cylinder valve and loss of solid UF_6 from the valve onto the ground.	UF_6	0.25	120 (continuous)	Ground
UF_6 vapor leak	A UF_6 transfer line leaks 5% of its flowing contents for 10 minutes due to potential compressor or pipe leakage.	UO_2F_2 HF	0.009 2.4	30	Stack
UF_6 liquid leak	A drain line from the UF_6 condensers leaks 5% of its flowing contents due to potential condenser or pipe leakage.	UO_2F_2 HF	0.0045 1.2	30	Stack
Loss of off-site electrical power	Off-site power is lost, which halts facility operations but does not result in significant releases to the environment.	No release	NA	NA	NA
Loss of cooling water	Cooling water flow to the UF_6 condenser is lost, and UF_6 vapor is released.	UO_2F_2 HF	0.009 2.4	2	Stack

TABLE E.4 (Cont.)

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Cylinder Transfer (Cont.)					
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
UF_6 cold trap rupture	A UF_6 cold trap is overfilled with UF_6 and ruptures during heating, releasing UF_6 into the process building.	UO_2F_2 HF	0.13 34	30	Stack
Extremely Unlikely Accidents (frequency: from 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, three full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Earthquake	A UF_6 compressor discharge pipe is cleanly sheared during a design-basis earthquake and leaks for 1 minute.	UO_2F_2 HF	0.018 4.7	30	Stack
Tornado	A design-basis tornado does not result in significant releases because UF_6 is a solid at ambient conditions.	No release	NA	NA	NA
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude flooding.	No release	NA	NA	NA
Small plane crash, two full 48G cylinders[b]	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,192	0 to 30 30 to 121.4	Ground

[a] Ground-level releases were assumed to occur outdoors on concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

[b] The frequency range of a small plane crash would be a function of site: extremely unlikely for the Paducah site, and incredible for the Portsmouth and K-25 sites.

TABLE E.5 Estimated Radiological Doses per Accident Occurrence for the Cylinder Overcontainer and Cylinder Transfer Options

		Maximum Dose[c]				Minimum Dose[c]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[a]	Frequency Category[b]	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Paducah Site									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	1.4	2.3×10^{-3}	2.6×10^{-1}	3.3×10^{-3}	6.3×10^{-2}	9.8×10^{-5}	3.0×10^{-2}
UF_6 cold trap rupture[d]	U	1.0×10^{-7}	1.5×10^{-4}	1.1×10^{-7}	5.6×10^{-4}	2.1×10^{-8}	2.8×10^{-5}	8.6×10^{-8}	2.3×10^{-4}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	1.5×10^{1}	1.5×10^{-2}	2.8×10^{1}	3.7×10^{-3}	1.3	1.9×10^{-3}	1.1
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	4.9	4.9×10^{-3}	3.7×10^{-1}	8.7×10^{-4}	6.4×10^{-1}	6.2×10^{-4}	5.2×10^{-2}
Portsmouth Site									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	2.2	2.2×10^{-3}	2.1×10^{-1}	3.3×10^{-3}	9.5×10^{-2}	9.3×10^{-5}	2.8×10^{-2}
UF_6 cold trap rupture[d]	U	1.0×10^{-7}	1.5×10^{-4}	1.1×10^{-7}	7.1×10^{-4}	2.1×10^{-8}	1.5×10^{-5}	8.6×10^{-8}	2.5×10^{-4}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	1.6×10^{1}	1.3×10^{-2}	3.2×10^{1}	3.7×10^{-3}	2.0	1.9×10^{-3}	1.6
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	5.3	4.3×10^{-3}	5.5×10^{-1}	8.7×10^{-4}	6.9×10^{-1}	6.2×10^{-4}	7.6×10^{-2}
K-25 Site									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	1.3	2.7×10^{-3}	4.3×10^{-1}	3.3×10^{-3}	6.0×10^{-2}	1.1×10^{-4}	5.9×10^{-2}
UF_6 cold trap rupture[d]	U	1.0×10^{-7}	1.8×10^{-4}	1.1×10^{-7}	1.2×10^{-3}	2.1×10^{-8}	3.6×10^{-5}	8.6×10^{-8}	5.0×10^{-4}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	1.6×10^{1}	1.3×10^{-2}	6.3×10^{1}	3.7×10^{-3}	2.4	1.9×10^{-3}	2.2
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	5.4	4.3×10^{-3}	7.4×10^{-1}	8.7×10^{-4}	6.9×10^{-1}	7.1×10^{-4}	1.0×10^{-1}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[c] Maximum and minimum doses reflect differences in assumed meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

[d] Applicable only to the cylinder transfer option.

TABLE E.6 Estimated Radiological Health Risks per Accident Occurrence for the Cylinder Overcontainer and Cylinder Transfer Options[a]

		Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI	Population	MEI	Population	MEI	Population	MEI	Population
Paducah Site									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	6×10^{-4}	1×10^{-6}	1×10^{-4}	1×10^{-6}	3×10^{-5}	5×10^{-8}	1×10^{-5}
UF_6 cold trap rupture[e]	U	4×10^{-11}	6×10^{-8}	4×10^{-11}	3×10^{-7}	8×10^{-12}	1×10^{-8}	4×10^{-11}	1×10^{-7}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	6×10^{-3}	7×10^{-6}	1×10^{-2}	1×10^{-6}	5×10^{-4}	1×10^{-6}	5×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	2×10^{-3}	2×10^{-6}	2×10^{-4}	3×10^{-7}	3×10^{-4}	3×10^{-7}	3×10^{-5}
Portsmouth Site									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	9×10^{-4}	1×10^{-6}	1×10^{-4}	1×10^{-6}	4×10^{-5}	5×10^{-8}	1×10^{-5}
UF_6 cold trap rupture[e]	U	4×10^{-11}	6×10^{-8}	6×10^{-11}	4×10^{-7}	8×10^{-12}	6×10^{-9}	4×10^{-11}	1×10^{-7}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	6×10^{-3}	6×10^{-6}	2×10^{-2}	1×10^{-6}	8×10^{-4}	1×10^{-6}	8×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	2×10^{-3}	2×10^{-6}	3×10^{-4}	3×10^{-7}	3×10^{-4}	3×10^{-7}	4×10^{-5}
K-25 Site									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	5×10^{-4}	1×10^{-6}	2×10^{-4}	1×10^{-6}	2×10^{-5}	6×10^{-8}	3×10^{-5}
UF_6 cold trap rupture[e]	U	4×10^{-11}	7×10^{-8}	6×10^{-11}	6×10^{-7}	8×10^{-12}	1×10^{-8}	4×10^{-11}	3×10^{-7}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	6×10^{-3}	7×10^{-6}	3×10^{-2}	1×10^{-6}	9×10^{-4}	1×10^{-6}	1×10^{-3}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	2×10^{-3}	2×10^{-6}	4×10^{-4}	3×10^{-7}	3×10^{-4}	4×10^{-7}	5×10^{-5}

a Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.0001; incredible (I), 0.000001.

b The bounding accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

c Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

d Maximum and minimum risks reflect differences in assumed meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

e Applicable only to the cylinder transfer option.

- The maximum radiological dose to noninvolved worker and general public MEIs (assuming an accident occurred) would be 0.077 rem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the U.S. Nuclear Regulatory Commission (NRC 1994).

- The overall radiological risk to noninvolved worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table E.6] by the annual probability of occurrence by the number of years of operation) would be less than 1 for all of the accidents.

E.3.2.2 Chemical Impacts

The accidents considered for the cylinder preparation options are listed in Table E.4. The results of the accident consequence modeling for chemical impacts are given in Tables E.7 and E.8. The results are presented as the (1) number of persons with potential for adverse effects and (2) the number of persons with potential for irreversible adverse effects. The results are given for the accident within each accident frequency category that would affect the largest number of persons (total of workers and off-site population) (Policastro et al. 1997). The impacts presented here are based on the assumption that the accidents would occur. The accidents listed in Tables E.7 and E.8 are not identical because an accident with the largest impacts for adverse effects might not lead to the largest impacts for irreversible adverse effects. The following general conclusions may be drawn from the chemical accident assessment:

- If the accidents identified in Table E.7 and E.8 did occur, the number of persons in the off-site population with potential for adverse effects would range from 0 to 1,900 (maximum corresponding to the vehicle-induced fire scenario at the Paducah site), and the number of off-site persons with potential for irreversible adverse effects would range from 0 to 1 (maximum corresponding to the corroded cylinder spill with pooling scenario at the Portsmouth site).

- If the accidents identified in Tables E.7 and E.8 did occur, the number of noninvolved workers with potential for adverse effects would range from 0 to 1,000 (maximum corresponding to the vehicle-induced fire scenario at the Portsmouth site), and the number of noninvolved workers with potential for irreversible adverse effects would range from 0 to 300 (maximum corresponding to the corroded cylinder spill with pooling scenario at the Paducah site).

TABLE E.7 Number of Persons with Potential for Adverse Effects from Accidents under the Cylinder Overcontainer and Cylinder Transfer Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Paducah Site									
Corroded cylinder spill, dry conditions	L	Yes	10	No	0	Yes[f]	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	690	Yes	14	Yes	7	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	910	Yes	1,900	Yes	4	Yes	3
Small plane crash, 2 full 48G cylinders	I	Yes	67	Yes	18	Yes[f]	0	No	0
Portsmouth Site									
Corroded cylinder spill, dry conditions	L	Yes	48	Yes[f]	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	850	Yes	12	Yes	2	Yes[f]	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	1,000	Yes	650	Yes	160	Yes	4
Small plane crash, 2 full 48G cylinders	I	Yes	700	Yes	22	No	0	No	0
K-25 Site									
Corroded cylinder spill, dry conditions	L	Yes	69	No	0	Yes[f]	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	700	Yes	18	Yes	47	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	770	Yes	550	No	0	Yes	12
Small plane crash, 2 full 48G cylinders	I	Yes	420	Yes	34	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum risks reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential adverse effects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the actual worker and general public population distributions were used, which did not show receptors at the MEI locations.

TABLE E.8 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under the Cylinder Overcontainer and Cylinder Transfer Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Paducah Site									
Corroded cylinder spill, dry conditions[f]	L	Yes[g]	0	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	130	Yes[g]	0	Yes	1	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	300	Yes	1	Yes	1	No	0
Small plane crash, 2 full 48G cylinders	I	No	0	No	0	No	0	No	0
Portsmouth Site									
Corroded cylinder spill, dry conditions	L	Yes[g]	0	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	90	Yes	1	Yes[g]	0	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	110	Yes	1	Yes[g]	0	No	0
Small plane crash, 2 full 48G cylinders[f]	I	No	0	No	0	No	0	No	0
K-25 Site									
Corroded cylinder spill, dry conditions	L	Yes	3	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	140	Yes	0	Yes	2	No	0
Vehicle-induced fire, 3 full 48G cylinders[f]	EU	No	0	No	0	No	0	No	0
Small plane crash, 2 full 48G cylinders[f]	I	No	0	No	0	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site population) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum risks reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential irreversible adverse effects to an individual.

[f] These accidents would result in the largest plume size for the frequency category, although no people would be affected.

[g] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the actual worker and general public population distributions were used, which did not show receptors at the MEI locations.

- Accidents resulting in a vehicle-induced fire involving three 48G cylinders during very stable (nighttime) meteorological conditions would have a very low probability of occurrence but could affect a large number of people.

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (20 years, 2009-2028). The results indicate that the maximum risk values would be less than 1 for all accidents, except the following:

  - *Potential Adverse Effects and Irreversible Adverse Effects:*

    Corroded cylinder spill, dry conditions (L, likely):
    Workers at the Paducah, Portsmouth, and K-25 sites

    Corroded cylinder spill, wet conditions – rain (U, unlikely):
    Workers at the Paducah, Portsmouth, and K-25 sites

  These risk values are conservative because the numbers of people affected were based on assuming (1) meteorological conditions that would result in the maximum reasonably foreseeable plume size (i.e., F stability and 1 m/s wind speed) and (2) wind in the direction that would lead to maximum numbers of individuals exposed for workers or for the general population.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible effects was estimated. All the bounding-case accidents shown in Table E.8 would involve releases of UF_6 and potential exposure to HF and uranium compounds. These exposures could be high enough to result in death for up to 1% of the persons experiencing irreversible adverse effects (Policastro et al. 1997). This would mean that for workers experiencing a range of 0 to 300 irreversible adverse effects, approximately 0 to 3 deaths would be expected. Similarly, of the general public experiencing a range of 0 to 1 irreversible adverse effects, less than 1 death would be expected. These are the maximum potential consequences of the accidents; the upper ends of the ranges result from the assumption of worst-case weather conditions, with the wind blowing in the direction where the highest number of people would be exposed.

E.3.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries for involved and noninvolved workers is calculated using industry-specific statistics from the Bureau of Labor Statistics, as reported by the National Safety Council (1995). Construction and manufacturing annual fatality and injury rates were used respectively for the construction and operational phases of the cylinder transfer facility lifetime; manufacturing fatality and injury rates were used for standard cylinder shipping preparation and overcontainer activities.

Figure E.10 shows the fatality and injury incidences for all workers associated with packaging cylinders in overcontainers across the ranges that might be required at the three current storage sites (i.e., ranges of 480 to 1,420 cylinders/yr at the Paducah site; 130 to 670 cylinders/yr at the Portsmouth site; and 120 to 234 cylinders/yr at the K-25 site). The impacts would increase directly as a function of the numbers of cylinders placed in overcontainers annually. Fatality incidences over the 20-year period of operations would all be less than 1 — ranging from about 0.029 to 0.087 at Paducah, about 0.007 to 0.041 at Portsmouth, and about 0.007 to 0.014 at K-25. On the basis of the ranges given for overcontainer requirements, the corresponding estimated injury incidence over the 20-year operations period would be from about 39 to 115 at Paducah, about 10 to 54 at Portsmouth, and about 9 to 18 at K-25.

Figures E.11 and E.12 give the fatality and injury incidences for all workers associated with transferring cylinder contents to new cylinders across the same potential range requirements as discussed above. It was assumed that any transfer facility would be constructed with a capacity near to or somewhat greater than the maximum number of cylinders expected to require processing (the actual numbers would not be determined until the time of cylinder shipment). Thus, the fatality and injury incidence estimates for construction of the transfer facility remain constant for each site across the range of annual cylinder processing requirements. However, data in the engineering analysis report (LLNL 1997) also showed that the relationship between number of cylinders processed annually and number of employees required per cylinder processed would not increase linearly. For example, more employees per cylinder would be required to process 100 cylinders than to process 1,000 cylinders. Therefore, the fatality and injury incidences would be lower at the K-25 and Portsmouth sites than at the Paducah site because of lower processing requirements; however, the fatality and injury incidences would also increase much more rapidly over the range processed annually at these sites, whereas the estimates for the Paducah site would remain relatively constant. Once the processing rate was above about 500 cylinders per year, fatality and injury incidences

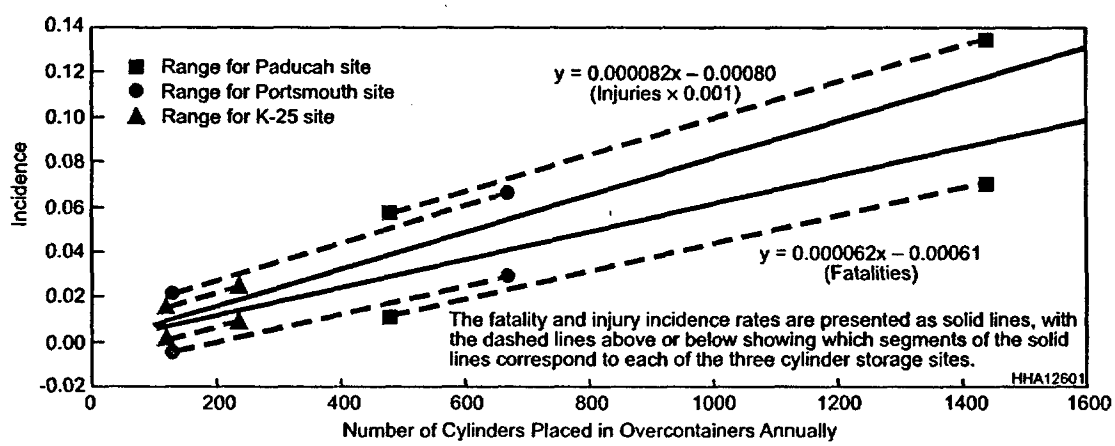

FIGURE E.10 Worker Fatality and Injury Incidence for Cylinder Overcontainer Activities

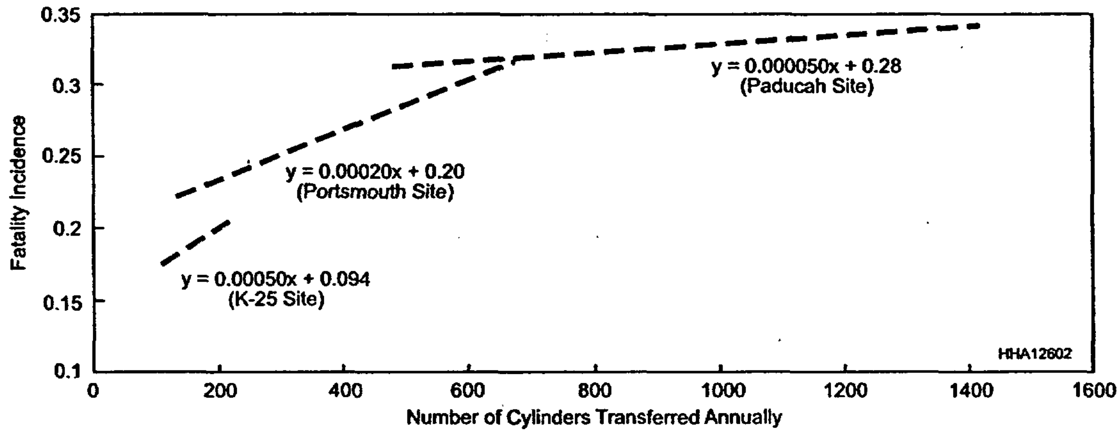

FIGURE E.11 Worker Fatality Incidence for Cylinder Transfer Activities

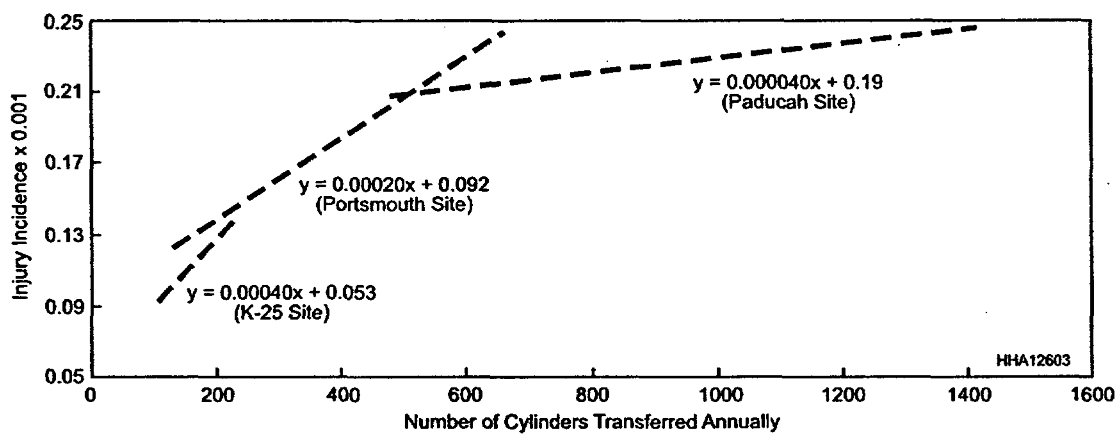

FIGURE E.12 Worker Injury Incidence for Cylinder Transfer Activities

would increase very little up to the maximum rate examined of about 1,600 cylinders per year. Fatality incidences for transfer facility construction and operation would all be less than 1, ranging from about 0.31 to 0.34 at Paducah, about 0.22 to 0.31 at Portsmouth and about 0.17 to 0.21 at K-25. On the basis of the assumed range in cylinder transfer requirements given above, the corresponding injury incidence would range from about 210 to 250 at Paducah, about 110 to 240 at Portsmouth, and about 94 to 140 at K-25.

Figure E.13 gives the fatality and injury incidences for all workers associated with preparation of standard cylinders for transport across the ranges that might be required at the three current storage sites (i.e., ranges from 0 to 940 cylinders/yr at Paducah, 0 to 540 cylinders/yr at Portsmouth, and 0 to 120 cylinders/yr at K-25). The impacts would increase directly as a function of the numbers of cylinders prepared annually. Fatality incidences would all be less than 1, ranging from 0 to about 0.043 at Paducah, 0 to about 0.025 at Portsmouth, and 0 to about 0.006 at K-25. The corresponding injury incidence would range from 0 to about 87 at Paducah, 0 to about 33 at Portsmouth, and 0 to about 7 at K-25.

E.3.3 Air Quality

Air quality impacts would result from the emissions associated with two distinct cylinder preparation options: (1) movement of cylinders in preparation for transportation, both those cylinders requiring overcontainers and standard cylinders, and (2) construction and operation of facilities to transfer contents from substandard cylinders to new ones. These two options are referred to in the following discussion as "overcontainer" and "transfer facility." No construction would be required for the overcontainer option. Descriptions of the methodology and assumptions are provided in Appendix C and Tschanz (1997).

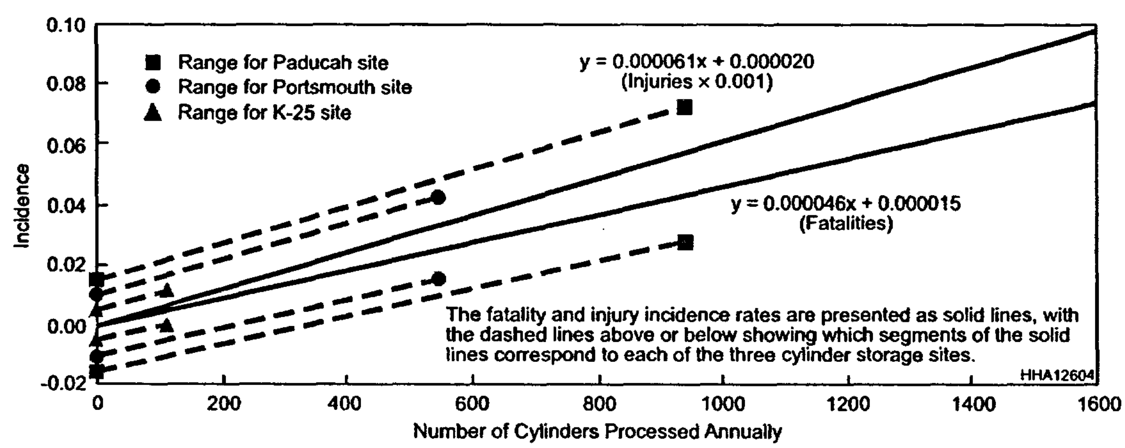

FIGURE E.13 Worker Fatality and Injury Incidence for Standard Cylinder Preparation

E.3.3.1 Paducah Site

Potential air quality impacts for carbon monoxide (CO), nitrogen oxides (NO_x), and PM_{10} (particulate matter with a mean diameter of 10 µm or less) from implementation of the overcontainer and transfer facility options at the Paducah site are presented in Table E.9. Ranges of impacts for the overcontainer option represent the assumptions of low to high numbers of cylinders that might be substandard at the time of transportation. All of the impacts for the overcontainer option would be negligible.

Construction of a transfer facility with a capacity to handle 1,600 cylinders per year would cause larger impacts than operation of the facility. The construction impacts would all be less than the applicable air quality standards. The largest impact, 62% of the standard, would occur for the 24-hour PM_{10} concentration (Table E.9). The PM_{10} concentrations would occur primarily as a result of fugitive dust from land disturbance. The estimated fugitive dust emissions from construction activities were based on a general emission factor that considers only the size of the disturbed area and, therefore, might be overestimated relative to the actual use of construction equipment. Mitigative measures, such as spraying water, would be expected to reduce the PM_{10} concentrations. More detailed information about the construction activities would be required to accurately assess the likely actual impacts.

Criteria pollutant concentrations during operations would be less than 2% of the values estimated to occur during construction, making all impacts negligible. Process stack emissions during operations would produce an annual average HF concentration of 3.1×10^{-5} µg/m^3 and UO_2F_2 concentration of 2.1×10^{-6} µg/m^3.

No quantitative estimate was made of the impacts on the criterion pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the Paducah site. McCracken County in the Paducah-Cairo Interstate Air Quality Control Region is currently in attainment for all criteria pollutant standards, including ozone. The pollutants most related to ozone formation that could result from the cylinder preparation options at the Paducah site would be hydrocarbons (HC) and NO_x. The potential effects on ozone of those emissions can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in McCracken County, as recorded in the Kentucky Division of Air Quality Control "Emissions Inventory" for 1995 (Hogan 1996). The estimated HC and NO_x emissions of 0.20 and 2.19 tons/yr during operation of the cylinder transfer facility would be only 0.034 and 0.006%, respectively, of the 1995 McCracken County emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the county. Emissions of HC and NO_x from the overcontainer option would be even smaller.

TABLE E.9 Air Quality Impacts of Cylinder Preparation Options at the Paducah Site

	Estimated Maximum Pollutant Concentrations from the Overcontainer Option							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]
CO	23 – 31	0.00078	3.0 – 4.0	0.00040	1.2 – 1.6	–	0.048 – 0.063	–
NO_x	3.5 – 4.7	–	0.46– 0.62	–	0.18 – 0.24	–	0.0073 – 0.0098	0.000098
PM_{10}	0.69 – 0.93	–	0.091 – 0.12	–	0.036 – 0.048	0.00032	0.0014 – 0.0019	0.000038

	Estimated Pollutant Concentrations from Construction of the Cylinder Transfer Facility							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]
CO	3,200	0.080	1,400	0.14	540	–	50	–
NO_x	450	–	200	–	77	–	7.2	0.072
PM_{10}	550	–	250	–	93	0.62	8.7	0.17

[a] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded. A hyphen indicates that no standard is available for this averaging period.

E.3.3.2 Portsmouth Site

The air quality impacts of cylinder preparation options at the Portsmouth site are shown in Table E.10. All impacts from construction of a transfer facility with a capacity for 960 cylinders per year at the Portsmouth site would be less than applicable air quality standards.

The impacts of criteria pollutant emissions during operation of the transfer facility would be negligible. Process stack emissions during operations would produce an annual average HF concentration of 1.9×10^{-5} μg/m³ and UO_2F_2 concentration of 1.5×10^{-6} μg/m³.

No quantitative estimate was made of the impacts on the criterion pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the Portsmouth site. Pike and Scioto Counties in the Wilmington-Chillicothe-Logan Air Quality Control Region are currently in attainment for all criteria pollutant standards, including ozone. The pollutant emissions most related to ozone formation that could result from the cylinder preparation options at the Portsmouth site would be HC and NO_x. The potential effects on ozone of those emissions can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in Pike and Scioto Counties, as recorded in the Ohio Environmental Protection Agency "Emissions Inventory" for 1990 (Juris 1996). The estimated HC and NO_x emissions of 0.18 and 1.65 tons/yr from operation of the cylinder transfer facility would be only 0.011 and 0.069%, respectively, of the 1990 two-county emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region. Emissions of HC and NO_x from the overcontainer option would be even smaller.

E.3.3.3 K-25 Site

The air quality impacts of cylinder preparation options at the K-25 site are shown in Table E.11. The NO_x and PM_{10} impacts from construction of a transfer facility with a capacity for 320 cylinders per year at the K-25 site would be larger in comparison with applicable air quality standards than would the impacts from a 1,600/yr cylinder transfer facility at the Paducah site. In part, this would be due to the fact that construction emissions would not decrease in proportion to the reduction in transfer capacity. Emissions of PM_{10} were assumed to be the same at all three sites.

The impacts of criteria pollutant emissions during operation of the transfer facility would be negligible. Process stack emissions during operations would produce an annual average HF concentration of 1.3×10^{-5} μg/m³ and UO_2F_2 concentration of 1.0×10^{-6} μg/m³.

No quantitative estimate was made of the impacts on the criterion pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the K-25 site. Anderson and Roane Counties in the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region are currently in attainment for all criteria pollutant standards, including ozone. The pollutant emissions most related to ozone formation that could result from the cylinder preparation

TABLE E.10 Air Quality Impacts of Cylinder Preparation Options at the Portsmouth Site

Estimated Maximum Pollutant Concentrations from the Overcontainer Option

	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]
CO	5.4 – 7.7	0.00019	0.91 – 1.3	0.00013	0.36 – 0.52	–	0.029 – 0.042	–
NO_x	0.81 – 1.2	–	0.14– 0.20	–	0.054– 0.079	–	0.0044 – 0.0064	0.000064
PM_{10}	0.16 – 0.23	–	0.027 – 0.040	–	0.011 – 0.016	0.00011	0.00088 – 0.0013	0.000026

Estimated Pollutant Concentrations from Construction of the Cylinder Transfer Facility

	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]
CO	2,600	0.065	660	0.066	250	–	29	–
NO_x	390	–	97	–	38	–	4.3	0.043
PM_{10}	560	–	140	–	54	0.36	6.2	0.12

[a] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded. A hyphen indicates that no standard is available for this averaging period.

TABLE E.11 Air Quality Impacts of Cylinder Preparation Options at the K-25 Site

	Estimated Maximum Pollutant Concentrations from the Overcontainer Option							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]	Range ($\mu g/m^3$)	Fraction of Standard[a]
CO	3.6 – 4.5	0.00011	0.54 – 0.67	0.00007	0.23 – 0.29	–	0.017 – 0.021	–
NO_x	0.56 – 0.70	–	0.083– 0.10	–	0.036– 0.044	–	0.0026 – 0.0033	0.00003
PM_{10}	0.11 – 0.14	–	0.016 – 0.020	–	0.0071 – 0.0088	0.00006	0.00052 – 0.00064	0.00001

	Estimated Pollutant Concentrations from Construction of the Cylinder Transfer Facility							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]	Concentration ($\mu g/m^3$)	Fraction of Standard[a]
CO	2,200	0.055	1,100	0.11	470	–	61	–
NO_x	320	–	160	–	69	–	8.9	0.089
PM_{10}	590	–	300	–	130	0.87	16	0.32

[a] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded. A hyphen indicates that no standard is available for this averaging period.

options at the K-25 site would be HC and NO_x. The potential effects on ozone of those pollutants can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in Anderson and Roane Counties, as recorded in the Tennessee Division of Air Pollution Control "Emissions Inventory" for 1995 (Conley 1996). The estimated HC and NO_x emissions of 0.14 and 1.20 tons/yr during operation of the cylinder transfer facility would be only 0.005 and 0.002%, respectively, of the 1995 two-county emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region. Emissions of HC and NO_x from the overcontainer option would be even smaller.

E.3.4 Water and Soil

The cylinder preparation options were assessed for potential impacts on surface water, groundwater, and soils. Details on the methodology and assumptions are presented in Appendix C and Tomasko (1997).

E.3.4.1 Surface Water

Potential impacts to surface water for the cylinder preparation options could occur during construction, normal operations, and postulated accident scenarios. For the cylinder overcontainer option and preparation of standard cylinders, however, there would be no impacts to surface water because no liquid wastes would be produced during construction and operations (LLNL 1997) and no accident scenarios were identified in the engineering analysis report that would directly release contaminated material to surface water (LLNL 1997). Secondary impacts to surface water would also be negligible because of the small concentrations associated with air deposition.

For the cylinder transfer facility, potential impacts to surface water during construction, normal operations, and accident scenarios would include changes in runoff, changes in quality, and floodplain encroachment.

E.3.4.1.1 Construction

Paducah Site. Construction of a cylinder transfer facility with a capacity for 1,600 cylinders per year at the Paducah site would increase runoff because about 15 acres (6.1 ha) of land would be replaced with paved lots and buildings (Table E.12). This increase in impermeable surface would produce a negligible impact on runoff because of the size of the existing watershed (0.4% of the land available).

TABLE E.12 Summary of Environmental Parameters for the Cylinder Transfer Facility

		Requirements per Site		
Option	Unit	Paducah	Portsmouth	K-25
Disturbed land area	acres	21	14	12
Paved area	acres	15	10	8
Construction water	million gal/yr	10	8	6.5
Construction wastewater	million gal/yr	5	4	3.3
Operations water	million gal/yr	9	7	6
Operations wastewater	million gal/yr	7.1	5.7	4.4
Radioactive release	Ci/yr	0.00078	0.00063	0.00049

Construction of the cylinder transfer facility would require about 10 million gal/yr (19 gpm) of water. This withdrawal would correspond to less than 0.000016% of average river flow and would produce a negligible impact on water levels and floodplains. During construction, the quality of nearby surface water could be affected by releases of wastewater containing small quantities of contaminants such as construction chemicals, organics, and suspended solids. About 5 million gal/yr (9.5 gpm) of construction wastewater would be discharged to nearby surface waters or to an appropriate wastewater sewer under a National Pollutant Discharge Elimination System (NPDES) permit. Once released, the wastewater would eventually be discharged to the Ohio River, resulting in dilution in excess of 12 million:1. All contaminant concentrations would be considerably below regulatory standards.

Portsmouth Site. Construction of a cylinder transfer facility with a capacity of 960 cylinders per year at the Portsmouth site would increase runoff because about 10 acres (4.1 ha) of land would be replaced with paved lots and buildings (Table E.12). This increase in impermeable surface would produce a negligible impact on runoff because of the size of the existing watershed (0.3% of the land available).

Construction of the cylinder transfer facility would require about 8 million gal/yr of water (15 gpm). Following usual practice at the Portsmouth site, this water would be withdrawn from wells, and there would be no impact to surface water. During construction, about 4 million gal/yr (8 gpm) of wastewater would be discharged to the river. Because of dilution (260,000:1), contaminant concentrations would be reduced to considerably below regulatory standards.

K-25 Site. Construction of a cylinder transfer facility with a capacity of 320 cylinders per year at the K-25 site would increase runoff because about 8 acres (4 ha) of land would be replaced with paved lots and buildings (Table E.12). This increase in impermeable surface would produce a negligible impact on runoff because of the size of the existing watershed (0.5% of the land available).

Construction of the cylinder transfer facility would require about 6.5 million gal/yr (12 gpm) of water. This withdrawal would correspond to about 0.00059% of average river flow and would produce a negligible impact on water levels and floodplains. During construction, about 3.3 million gal/yr (6 gpm) of wastewater would be discharged to the river. Because of dilution (340,000:1), contaminant concentrations would be reduced to considerably below regulatory standards.

E.3.4.1.2 Operations

Paducah Site. For normal operations of the 1,600/yr cylinder transfer facility at the Paducah site, approximately 9 million gal/yr (17.1 gpm) of water would be withdrawn from surface water (Table E.12). This withdrawal would represent less than 0.000014% of the average river flow and would produce a negligible impact on water levels and floodplains.

About 7.1 million gal/yr (14 gpm) of wastewater would be discharged to the river during normal operations. This water would consist of sanitary wastewater, blowdown water from the cooling tower, industrial wastewater, and process water (LLNL 1997). This discharge would represent about 0.000012% of the average river flow and would produce a negligible impact on water levels and floodplains.

In addition to producing physical impacts to surface water, normal operations would also impact surface water quality. Approximately 0.00078 Ci/yr (about 112 μg/L) of uranium would be released to the river at the point of discharge (LLNL 1997). Although the concentration at the outfall would exceed the proposed U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 20 μg/L (EPA 1996) used as a guideline, the resulting uranium concentration (as well as the concentrations of other chemicals) in the river would be less than 20 μg/L because of dilution (9 million:1).

Portsmouth Site. For normal operations of the 960/yr cylinder transfer facility at the Portsmouth site, about 7 million gal/yr (13 gpm) of water would be required (Table E.12). Because this water would be withdrawn from wells, there would be no surface water impacts.

About 5.7 million gal/yr (11 gpm) of wastewater would be discharged to the river. This water would consist of sanitary wastewater, blowdown water, industrial wastewater, and process water (LLNL 1997). This discharge would represent about 0.00052% of the average river flow and would produce a negligible impact on water levels and floodplains.

Normal operations would also impact surface water quality. Approximately 0.00063 Ci/yr of uranium would be released to surface water (about 112 μg/L at the point of discharge). Although the concentration of uranium at the outfall would exceed the 20 μg/L guideline (EPA 1996), the resulting uranium concentration (as well as other chemicals) in the river would be less 20 μg/L because of dilution (200,000:1).

K-25 Site. For normal operation of the 320/yr cylinder transfer facility at the K-25 site, about 6 million gal/yr (11 gpm) of water would be required (Table E.12). This rate of withdrawal would represent about 0.00054% of the average river flow and would produce a negligible impact on water levels and floodplains.

About 4.4 million gal/yr (8 gpm) of wastewater would be discharged to the river. This water would consist of sanitary wastewater, blowdown water, industrial wastewater, and process water (LLNL 1997). This discharge would represent about 0.00038% of the average river flow and would produce a negligible impact on water levels and floodplains.

Normal operations would also impact surface water quality. Approximately 0.00049 Ci/yr of uranium would be released to surface water (about 112 μg/L at the point of discharge). Although the concentration of uranium at the outfall would exceed the 20 μg/L guideline (EPA 1996), the resulting uranium concentration (as well as other chemicals) in the river would be less than 20 μg/L because of dilution (255,000:1).

E.3.4.1.3 Accident Scenarios

No accidents are identified in LLNL (1997) that would directly affect surface water at any of the three storage sites. Secondary impacts resulting from deposition of airborne contaminants would not be measurable because of low concentrations in the deposited material.

E.3.4.2 Groundwater

For the cylinder overcontainer option and during preparation of standard cylinders, there would be no impacts to groundwater for any of the sites because there would be no discharges to the surface (LLNL 1997). For the cylinder transfer facility, impacts could occur during construction and normal operations; however, there would be no impacts from potential accidents because no accidents were identified in the engineering analysis report (LLNL 1997) that would release contaminants to the ground. Secondary impacts from air deposition would not be measurable because of the small concentrations of deposited material.

E.3.4.2.1 Construction

Paducah Site. Construction of the cylinder transfer facility at the Paducah site would result in decreased permeability of about 15 acres (6.1 ha) of land (Table E.12). This loss of permeable land would reduce recharge, increase depth to the water table, and change the direction of groundwater flow; however, because the affected area would be small (about 0.4% of the land available), the impacts would be local and negligible.

During construction, groundwater quality would also be impacted. For example, stockpiled chemicals could be mobilized by precipitation and infiltrate the surficial aquifer. By following good engineering and construction practices (e.g., covering chemicals to prevent interaction with rain, promptly cleaning up any spills, and providing retention basins to catch and hold contaminated runoff), groundwater concentrations would be less than the EPA guidelines.

Portsmouth Site. Construction of the cylinder transfer facility at the Portsmouth site would decrease the permeability of about 10 acres (4.1 ha) (Table E.12). This loss of permeable land would reduce recharge, increase depth to the water table, and change the direction of groundwater flow; however, because the affected area would be small (about 0.3% of the land available), the impacts would be local and negligible.

Construction of the cylinder transfer facility would require extracting 4 million gal/yr (8 gpm) from wells. This extraction would increase the daily withdrawal by less than 0.1% and would produce a negligible impact on depth to groundwater and direction of groundwater flow. Construction could also impact groundwater quality. By following good engineering and construction practices, groundwater concentrations would be less than the EPA guidelines.

K-25 Site. Construction of the cylinder transfer facility would decrease the permeability of about 8 acres (3.2 ha) (Table E.12). This loss of permeable land would reduce recharge, increase depth to the water table, and change the direction of groundwater flow; however, because the affected area would be small (about 0.5% of the land available), the impacts would be local and negligible. During construction, groundwater quality would also be impacted. By following good engineering and construction practices, groundwater concentrations would be less than the EPA guidelines.

E.3.4.2.2 Operations

Paducah Site. No impacts to groundwater would occur during normal operations at the Paducah site because no groundwater would be used and there would be no discharges to the ground.

Portsmouth Site. Normal operation of the cylinder transfer facility at the Portsmouth site would required an additional 7 million gal/yr of withdrawal from wells (Table E.12). This rate of withdrawal would represent an increase in daily extraction of about 0.1%. Because the rate of increased use would be small, impacts to the depth to the groundwater and its flow direction would be negligible. No impacts would occur to groundwater quality because there would be no direct discharges to the ground.

K-25 Site. No impacts to groundwater would occur during normal operations at the K-25 site because no groundwater would be used and there would be no discharges to the ground.

E.3.4.3 Soil

For the cylinder overcontainer option and during preparation of standard cylinders, there would be no impacts to soils from any of the three cases because there would be no discharges to the ground. For the cylinder transfer facility, the only impacts to the three sites would occur during construction; for normal operations, there would be no discharges to the ground, and there are no accidents identified in the engineering analysis report (LLNL 1997) that would lead to direct contamination of the soil. Secondary impacts to the soil from air deposition would be negligible because of the small concentrations of contaminants in the deposited material. Impacts from construction of the cylinder transfer facility include changes in topography, permeability, quality, and erosion potential.

E.3.4.3.1 Paducah Site

At the Paducah site, construction of a cylinder transfer facility with a capacity of 1,600 cylinders per year would disturb 21 acres (8.5 ha) of land (Table E.12). In the area of the construction, topography would be altered, permeability would be decreased in paved areas or areas that were compacted, permeability would increase in aerated areas, and erosion potential would decrease in compacted areas and increase in areas that were aerated. In general, these impacts would be negligible because the affected area would be small (about 0.6% of the land available), and in many cases, the impacts would be temporary (with regrading and reseeding, the soil would return to its former condition).

In addition to these physical changes, construction could also have a chemical impact on soil. By following good engineering and construction practices (e.g., covering chemicals with tarps, cleaning up spills as soon as they occur, and providing retention basins to catch and hold surface runoff), impacts to soil quality would be negligible.

E.3.4.3.2 Portsmouth Site

At the Portsmouth site, construction of a cylinder transfer facility with a capacity for 960 cylinders per year would disturb 14.3 acres (5.8 ha) of land (Table E.12). In the area of the construction, topography would be altered, permeability would be decreased in paved areas or areas that were compacted, permeability would increase in aerated areas, and erosion potential would decrease in compacted areas and increase in areas that were aerated. In general, these impacts would be negligible because the affected area would be small (about 0.4% of the land available), and in many cases, the impacts would be temporary (with regrading and reseeding, the soil would return to its former condition).

In addition to these physical changes, construction could also have a chemical impact on soil. By following good engineering and construction practices, impacts to soil quality would be negligible.

E.3.4.3.3 K-25 Site

At the K-25 site, construction of a cylinder transfer facility with a capacity for 320 cylinders per year would disturb 12 acres (4.9 ha) of land (Table E.12). In the area of the construction, topography would be altered, permeability would be decreased in paved areas or areas that were compacted, permeability would increase in aerated areas, and erosion potential would decrease in compacted areas and increase in areas that were aerated. In general, these impacts would be negligible because the affected area would be small (about 0.7% of the land available), and in many cases, the impacts would be temporary (with regrading and reseeding, the soil would return to its former condition).

In addition to these changes, construction could also have a chemical impact on soil. By following good engineering and construction practices, impacts to soil quality would be negligible.

E.3.5 Socioeconomics

The impacts of cylinder preparation on socioeconomic activity were estimated for a region of influence (ROI) at the three storage sites. Additional details regarding the assessment methodology is presented in Appendix C and Allison and Folga (1997).

Cylinder preparation would likely have a small impact on socioeconomic conditions in the ROIs surrounding the three sites described in Chapter 3, Sections 3.1.8, 3.2.8, and 3.3.8. This is partly because a major proportion of expenditures associated with procurement for the preoperation and operation of each preparation option would flow outside the ROI to other locations in the United States, reducing the concentration of local economic effects of each facility.

Slight changes in employment and income would occur in each ROI as a result of local spending of personal consumption expenditures derived from employee wages and salaries, local procurement of goods and services required for cylinder preparation activities, and other local investment associated with preoperations and operations. In addition to creating new (direct) jobs at each site, cylinder preparation would also create indirect employment and income in the ROI as a result of jobs and procurement expenditures at each site. Jobs and income created directly by cylinder preparation, together with indirect activity in the ROI, would contribute slightly to a reduction in unemployment in the ROI surrounding each site. Minimal impacts would be expected on local population growth and, consequently, on local housing markets and local fiscal conditions.

The effects of preoperating and operating cylinder preparation on regional economic activity, measured in terms of employment and personal income, and on population, housing, and local public revenues and expenditures are discussed in Sections E.3.5.1 through E.3.5.3. Impacts are presented for cylinder preparation at each of the storage sites for the peak year of preoperations and the first year of operations. The impacts of cylinder preparation at the three storage sites are given in Table E.13.

E.3.5.1 Paducah Site

E.3.5.1.1 Impacts from Cylinder Preparation Using Overcontainers

During the peak year of preoperations for cylinder preparation using overcontainers, fewer than 5 direct jobs would be created at the site and fewer than 5 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, fewer than 5 jobs would be created. Preoperational activities would also produce direct and indirect income in the ROI surrounding the site, with \$0.2 million of total income produced during the peak year. During the first year of operations involving overcontainers, 230 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with \$9 million in total income produced. Activities associated with overcontainers would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.02 percentage points from 1999 through 2028.

Preoperations involving overcontainers would be expected to generate direct in-migration of fewer than 5 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to fewer than 5 in the peak year. Operational

TABLE E.13 Potential Socioeconomic Impacts of the Cylinder Preparation Options at the Three Sites

	Cylinder Overcontainers		Cylinder Transfer Facility		Standard Cylinder Preparation	
Site/Parameter	Preoperation[a]	Operations[b]	Construction[a]	Operations[b]	Preoperation[a]	Operations[b]
Paducah Site						
Economic activity in the ROI						
Direct jobs	<5	120	260	200	<5	60
Indirect jobs	<5	110	130	170	<5	60
Total jobs	<5	230	390	370	<5	120
Direct income ($ million)	0.1	8	12	10	0.1	4
Total income ($ million)	0.2	9	14	13	0.1	5
Population in-migration into the ROI	<5	230	440	390	<5	100
Housing demand						
Number of units in the ROI	<5	80	160	140	<5	40
Public finances						
Change in ROI fiscal balance (%)	0	0.1	0.3	0.3	0	0.1
Portsmouth Site						
Economic activity in the ROI						
Direct jobs	<5	100	190	160	<5	50
Indirect jobs	<5	80	90	180	<5	40
Total jobs	<5	180	280	350	<5	90
Direct income ($ million)	0.1	6	8	8	0.1	3
Total income ($ million)	0.2	7	10	11	0.1	4
Population in-migration into the ROI	<5	200	320	330	<5	100
Housing demand						
Number of units in the ROI	<5	80	120	120	<5	40
Public finances						
Change in ROI fiscal balance (%)	0	0.1	0.2	0.2	0	0.1

TABLE E.13 (Cont.)

Site/Parameter	Cylinder Overcontainers		Cylinder Transfer Facility		Standard Cylinder Preparation	
	Preoperation[a]	Operations[b]	Construction[a]	Operations[b]	Preoperation[a]	Operations[b]
K-25 Site						
Economic activity in the ROI						
Direct jobs	<5	80	130	130	<5	40
Indirect jobs	<5	120	160	380	<5	60
Total jobs	<5	200	290	510	<5	100
Direct income ($ million)	0.1	5	6	7	0.1	2
Total income ($ million)	0.2	6	9	13	0.1	3
Population in-migration into the ROI	<5	190	220	240	<5	80
Housing demand						
Number of units in the ROI	<5	70	80	90	<5	30
Public finances						
Change in ROI fiscal balance (%)	0	0.1	0.04	0.04	0	0.01

[a] Impacts are for peak year of preoperation or construction, 2007. The preoperational (construction) phase was assessed from 1999 through 2008.

[b] Impacts are the annual averages for operations for the period 2009 through 2028.

activities for cylinder overcontainers would be expected to generate direct and indirect job in-migration of 230 in the first year of operations. Preoperational and operational activities for overcontainers would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.01 percentage points from 1999 through 2028.

Cylinder overcontainer activities would generate a demand for fewer than 5 additional rental housing units during the peak year of preoperations, representing an impact of 0.1% on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 80 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 1.8% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of preoperations, fewer than 5 people would be expected to in-migrate into the ROI, leading to essentially no increase over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 230 in-migrants would be expected, leading to an increase of 0.1% in local revenues and expenditures.

E.3.5.1.2 Impacts from a Cylinder Transfer Facility

During the peak year of construction of a cylinder transfer facility, 260 direct jobs would be created at the site and 130 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 390 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $14 million of total income produced during the peak year. During the first year of operations of the cylinder transfer facility, 370 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $13 million in total income produced. Construction and operation of the transfer facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.04 percentage points from 1999 through 2028.

Construction of the cylinder transfer facility would be expected to generate direct in-migration of 360 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to 440 in the peak year. Operation of the cylinder transfer facility would be expected to generate direct and indirect job in-migration of 390 in the first year of operations. Construction and operation of the transfer facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.02 percentage points from 1999 through 2028.

The cylinder transfer facility would generate a demand for 160 additional rental housing units during the peak year of construction, representing an impact of 10.4% on the projected number of vacant rental housing units in the ROI (Table E.13). The demand for 140 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 3.0% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of construction, 440 people would be expected to in-migrate into the ROI, leading to an increase of 0.3% over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 390 in-migrants would be expected, leading to an increase of 0.3% in local revenues and expenditures.

E.3.5.1.3 Impacts from Standard Cylinder Preparation

During the peak year of preoperational activities for standard cylinder preparation, fewer than 5 direct jobs would be created at the site and fewer than 5 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, fewer than 5 jobs would be created. Preoperational activities would also produce direct and indirect income in the ROI surrounding the site, with $0.1 million of total income produced during the peak year. During the first year of operations for standard cylinder preparation, 120 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $5 million in total income produced. Preoperational and operational activities for standard cylinder preparation would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 percentage points from 1999 through 2028.

Preoperational activities for standard cylinder preparation would be expected to generate direct in-migration of fewer than 5 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to fewer than 5 in the peak year. Operational activities for standard cylinder preparation would be expected to generate direct and indirect job in-migration of 100 in the first year of operations. Preoperational and operational activities would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.01 percentage points from 1999 through 2028.

Standard cylinder preparation activities would generate a demand for fewer than 5 additional rental housing units during the peak year of preoperations, representing an impact of 0.0% on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 40 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.8% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of preoperations, fewer than 5 people would be expected to in-migrate into the ROI, leading to essentially no increase over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 100 in-migrants would be expected, leading to an increase of 0.1% in local revenues and expenditures.

E.3.5.2 Portsmouth Site

E.3.5.2.1 Impacts from Cylinder Preparation Using Overcontainers

During the peak year of preoperation for standard cylinder preparation using overcontainers, fewer than 5 direct jobs would be created at the site and fewer than 5 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, fewer than 5 jobs would be created. Preoperation activities would also produce direct and indirect income in the ROI surrounding the site, with $0.2 million of total income produced during the peak year. During the first year of operations involving overcontainers, 180 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $7 million in total income produced. Activities associated with overcontainers would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.02 percentage points from 1999 through 2028.

Preoperations involving overcontainers would be expected to generate direct in-migration of fewer than 5 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to fewer than 5 in the peak year. Operational activities for cylinder overcontainers would be expected to generate direct and indirect job in-migration of 200 in the first year of operations. Preoperational and operational activities for overcontainers would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.01 percentage points from 1999 through 2028.

Cylinder overcontainer activities would generate a demand for fewer than 5 additional rental housing unit during the peak year of preoperations, representing an impact of 0.1% on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 80 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 1.6% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of preoperations, fewer than 5 people would be expected to in-migrate into the ROI, leading to essentially no increase over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 200 in-migrants would be expected, leading to an increase of 0.1% in local revenues and expenditures.

E.3.5.2.2 Impacts from a Cylinder Transfer Facility

During the peak year of construction of a cylinder transfer facility, 190 direct jobs would be created at the site and 90 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 280 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $10 million of total income produced during the peak year. During the first year of operations of the cylinder transfer facility, 350 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $11 million in total income produced. Construction and operation of the transfer facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.03 percentage points from 1999 through 2028.

Construction of the cylinder transfer facility would be expected to generate direct in-migration of 260 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to 320 in the peak year. Operation of the cylinder transfer facility would be expected to generate direct and indirect job in-migration of 330 in the first year of operations. Construction and operation of the transfer facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.01 percentage points from 1999 through 2028.

The cylinder transfer facility would generate a demand for 120 additional rental housing units during the peak year of construction, representing an impact of 5.9% on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 120 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.2% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of construction, 320 people would be expected to in-migrate into the ROI, leading to an increase of 0.2% over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 330 in-migrants would be expected, leading to an increase of 0.2% in local revenues and expenditures.

E.3.5.2.3 Impacts from Standard Cylinder Preparation

During the peak year of preoperational activities for standard cylinder preparation, fewer than 5 direct jobs would be created at the site and fewer than 5 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, fewer than 5 jobs would be created. Preoperational activities would also produce direct and indirect income in the ROI surrounding the site, with $0.1 million of total income produced during the peak year. During the first year of operations for standard cylinder preparation, 90 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $4 million in total income produced. Preoperational and operational activities for standard cylinder preparation would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 percentage points from 1999 through 2028.

Preoperational activities for standard cylinder preparation would be expected to generate direct in-migration of fewer than 5 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to fewer than 5 in the peak year. Operational activities for standard cylinder preparation would be expected to generate direct and indirect job in-migration of 100 in the first year of operations. Preoperational and operational activities would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.004 percentage points from 1999 through 2028.

Standard cylinder preparation activities would generate a demand for fewer than 5 additional rental housing units during the peak year of preoperations, representing essentially no impact on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 40 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.7% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of preoperations, fewer than 5 people would be expected to in-migrate into the ROI, leading to essentially no increase over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 100 in-migrants would be expected, leading to an increase of 0.1% in local revenues and expenditures.

E.3.5.3 K-25 Site

E.3.5.3.1 Impacts from Cylinder Preparation Using Overcontainers

During the peak year of preoperations for cylinder preparation using overcontainers, fewer than 5 direct jobs would be created at the site and fewer than 5 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, fewer than 5 jobs would be created. Preoperational activities would also produce direct and indirect income in the ROI surrounding the site, with $0.2 million of total income produced during the peak year. During the first year of operations involving overcontainers, 200 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $6 million in total income produced. Activities associated with overcontainers would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 percentage points from 1999 through 2028.

Preoperations involving overcontainers would be expected to generate direct in-migration of fewer than 5 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to fewer than 5 in the peak year. Operational activities for cylinder overcontainers would be expected to generate direct and indirect job in-migration of 190 in the first year of operations. Preoperational and operational activities for overcontainers would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.03 percentage points from 1999 through 2028.

Cylinder overcontainer activities would generate a demand for fewer than 5 additional rental housing units during the peak year of preoperations, representing an impact of 0.1% on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 70 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.6% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of preoperations, fewer than 5 people would be expected to in-migrate into the ROI, leading to essentially no increase over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 190 in-migrants would be expected, leading to an increase of 0.1% in local revenues and expenditures.

E.3.5.3.2 Impacts from a Cylinder Transfer Facility

During the peak year of construction of a cylinder transfer facility, 130 direct jobs would be created at the site and 160 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 290 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $9 million of total income produced during the peak year. During the first year of operations of the cylinder transfer facility, 510 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $13 million in total income produced. Construction and operation of the transfer facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 percentage points from 1999 through 2028.

Construction of the cylinder transfer facility would be expected to generate direct in-migration of 170 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to 220 in the peak year. Operation of the cylinder transfer facility would be expected to generate direct and indirect job in-migration of 240 in the first year of operations. Construction and operation of the transfer facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.004 percentage points from 1999 through 2028.

The cylinder transfer facility would generate a demand for 80 additional rental housing units during the peak year of construction, representing an impact of 1.5% on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 90 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.8% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of construction, 220 people would be expected to in-migrate into the ROI, leading to an increase of 0.04% over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 240 in-migrants would be expected, leading to an increase of 0.04% in local revenues and expenditures.

E.3.5.3.3 Impacts from Standard Cylinder Preparation

During the peak year of preoperational activities for standard cylinder preparation, fewer than 5 direct jobs would be created at the site and fewer than 5 additional jobs indirectly in the ROI (Table E.13) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, fewer than 5 jobs would be created. Preoperational activities would also produce direct and indirect income in the ROI surrounding the site, with $0.1 million of total income produced during the peak year. During the first year of operations for standard cylinder preparation, 100 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with $3 million in total income produced. Preoperational and operational activities for standard cylinder preparation would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 percentage points from 1999 through 2028.

Preoperational activities for standard cylinder preparation would be expected to generate direct in-migration of fewer than 5 in the peak year (Table E.13). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to fewer than 5 in the peak year. Operational activities for cylinder preparation would be expected to generate direct and indirect job in-migration of 80 in the first year of operations. Preoperational and operational activities would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.001 percentage points from 1999 through 2028.

Standard cylinder preparation activities would generate a demand for fewer than 5 additional rental housing unit during the peak year of preoperations, representing essentially no impact on the projected number of vacant rental housing units in the ROI (Table E.13). A demand for 30 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.3% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of preoperations, fewer than 5 people would be expected to in-migrate into the ROI, leading to essentially no increase over ROI-forecasted baseline revenues and expenditures (Table E.13). In the first year of operations, 80 in-migrants would be expected, leading to an increase of 0.01% in local revenues and expenditures.

E.3.6 Ecology

Predicted concentrations of contaminants in environmental media were compared with benchmark values of toxic and radiological effects to assess impacts to terrestrial and aquatic biota. Discussion of assessment methodology is presented in Appendix C.

No ecological impacts would be expected during preparation of standard cylinders. Under the cylinder overcontainer option, no site preparation or construction would occur. Normal operations would not result in impacts to surface water, groundwater, or soil (Section E.3.4). Atmospheric releases of contaminants would include only criteria pollutants, and emission levels would be expected to be extremely low (Section E.3.3). Therefore, impacts of the cylinder overcontainer option to ecological resources would be negligible.

Impacts to ecological resources could result from construction of a cylinder transfer facility. Impacts could include mortality of individual organisms, habitat loss, or changes in biotic communities. Impacts due to operation of a cylinder transfer facility could result from exposure to airborne contaminants or contaminants released to soils, groundwater, or surface waters or changes in surface water or groundwater quality or flow rates.

E.3.6.1 Paducah Site

Site preparation for the construction of a cylinder transfer facility at the Paducah site would require the disturbance of approximately 21 acres (9 ha), including the permanent replacement of approximately 15 acres (6 ha), primarily with structures and paved areas. Existing vegetation would be destroyed during land clearing activities. Determination of the vegetation communities that would be eliminated by site preparation would depend on the exact location of the facility. Communities occurring on undeveloped land at the site are relatively common and well represented in the vicinity of the site; however, impacts to high quality native plant communities might occur if facility construction required disturbance to vegetation communities outside of the currently fenced site area (see Section E.3.9 for a discussion of land use). Construction of the transfer facility would not be expected to threaten the local population of any species. The loss of up to 21 acres (9 ha) of undeveloped land would constitute a moderate adverse impact to vegetation. Erosion of exposed soil at the construction site could reduce the effectiveness of restoration efforts and create sedimentation downgradient of the site. The implementation of standard erosion control measures, installation of storm-water retention ponds, and immediate replanting of disturbed areas with native species would help minimize impacts to vegetation. Impacts due to facility construction are shown in Table E.14.

TABLE E.14 Potential Impacts to Ecological Resources from Construction of the Cylinder Transfer Facility at the Paducah Site

Resource	Type of Impact	Degree of Impact
Vegetation	Loss of 21 acres	Moderate adverse impact
Wildlife	Loss of 15 to 21 acres	Moderate adverse impact
Wetlands	Loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Negligible impact
Protected species	Destruction, habitat loss	Potential adverse impact

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land-clearing activities. More mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities and competition would increase in these areas, potentially reducing the chances of survival or reproductive capacity of displaced individuals. Some wildlife species would be expected to quickly recolonize replanted areas near the facility following completion of construction. The permanent loss of 15 to 21 acres (6 to 9 ha) of habitat would not be expected to threaten the local population of any wildlife species because similar habitat would be available in the vicinity of the site. Construction of a cylinder transfer facility would be considered a moderate adverse impact to wildlife.

Impacts to surface water and groundwater quality during construction are expected to be negligible (Section E.3.4). Thus, construction-derived impacts to aquatic biota would also be expected to be negligible. Wetlands could potentially be impacted by filling or draining during construction. In addition, impacts to wetlands due to alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur if the facility were located immediately adjacent to wetland areas. However, impacts to wetlands would be minimized by maintaining a buffer area around wetlands during construction of the facility. Unavoidable impacts to wetlands would require a *Clean Air Act* Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies.

Critical habitat has not been designated for any federal- or state-listed threatened or endangered species at the Paducah site. Prior to construction of the transfer facility, a survey would be conducted for federal- and state-listed threatened, endangered, or candidate species, or species of special concern. Impacts to these species could thus be avoided or, when impacts were unavoidable, appropriate mitigation could be developed.

Water withdrawal from surface waters or groundwater, as well as wastewater discharge, during facility construction and operation could potentially alter water levels. The changes in water levels could in turn affect aquatic ecosystems, including wetlands, such as those located along the periphery of these surface water bodies. However, water-level changes due to water withdrawal and wastewater discharge would be negligible (Section E.3.4). Therefore, impacts to wetlands and aquatic communities would be expected to be negligible.

Ecological resources in the vicinity of the transfer facility would be exposed to atmospheric emissions from the boiler stack and process stack; however, emission levels would be expected to be extremely low (Section E.3.3.1), well below concentrations known to adversely affect biota. Resulting impacts to biota would be expected to be negligible. Impacts due to facility operation are shown in Table E.15.

TABLE E.15 Potential Impacts to Ecological Resources from Operation of the Cylinder Transfer Facility at the Paducah Site

Contaminant	Biota	Maximum Exposure	Impact
HF	Wildlife	3.1×10^{-5} µg/m^3	Negligible
UO_2F_2 in air	Wildlife	2.1×10^{-6} µg/m^3	Negligible
Uranium in surface water	Aquatic	112 µg/L	Negligible

Effluent discharges to surface waters could contain a number of chemical contaminants. Facility wastewater would have a uranium concentration of about 112 µg/L in the undiluted effluent (Section E.3.4.1). Dilution of the discharge in the receiving stream by a factor in excess of 150,000 would result in negligible concentrations (Section E.3.4.1). Thus, impacts to aquatic biota in the vicinity of the outfall would be negligible.

Facility accidents, as discussed in Section E.3.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors such as location of the accident, season, and meteorological conditions.

E.3.6.2 Portsmouth Site

Construction of a cylinder transfer facility at the Portsmouth site would result in the types of impacts associated with the Paducah facility. However, a smaller area would be required. Facility construction would disturb approximately 14 acres (6 ha), including the permanent replacement of 10 acres (4 ha), primarily with structures and paved areas. Construction of the transfer facility would not be expected to threaten the local population of any species. In addition to site-specific surveys for protected species, avoidance of wooded areas would reduce the potential for impacts to the sharp-shinned hawk (state-listed as endangered) and Indiana bat (federal- and state-listed as endangered). The loss of up to 14 acres (6 ha) of undeveloped land and 10 to 14 acres (4 to 6 ha) of habitat would constitute a moderate adverse impact to vegetation and wildlife.

Operation of a cylinder transfer facility at the Portsmouth site would result in lower atmospheric emissions of contaminants than predicted for the Paducah facility. Resulting impacts to biota would, therefore, also be negligible. Uranium concentrations in discharges to surface water would be slightly lower than predicted for the Paducah facility. Resulting impacts to aquatic biota would also be negligible.

E.3.6.3 K-25 Site

Construction of a cylinder transfer facility at the K-25 site would result in the types of impacts associated with the Paducah and Portsmouth facilities. However, a smaller area would be required. Facility construction would disturb approximately 12 acres (5 ha), including the permanent replacement of 8 acres (3 ha), primarily with structures and paved areas. Construction of the transfer facility would not be expected to threaten the local population of any species. The loss of up to 12 acres (5 ha) of undeveloped land and 9 to 12 acres (4 to 5 ha) of habitat would constitute a moderate adverse impact to vegetation and wildlife.

Operation of a cylinder transfer facility at the K-25 site would result in lower atmospheric emissions of contaminants than predicted for the Paducah or Portsmouth facilities. Resulting impacts to biota would, therefore, also be negligible. Uranium concentrations in discharges to surface water would be slightly lower than predicted for the Paducah or Portsmouth facilities. Resulting impacts to aquatic biota would also be negligible.

E.3.7 Waste Management

Estimates of waste generation were based on the total number of cylinders at each site. No liquid wastes would be expected at the sites as a result of cylinder shipment activities from either standard cylinders or cylinders in overcontainers. The only solid waste generated in these activities would be personal protective equipment and wipes and rags that would be used to remove surface contamination on the cylinders. These wastes are categorized as combustible solid low-level radioactive waste (LLW) and are shown in Table E.16 for each of the three sites. It was assumed that the LLW would be generated during removal of surface contamination and would be independent of the cylinders being standard or substandard. Thus, the amount of waste in this operation would be proportional to the total number of cylinders at the site. It was assumed that no cylinder breaches would occur inside the overcontainers during transportation.

The waste input resulting from the cylinder overcontainer operations would have minimal impact on radioactive waste management capabilities at any of the three sites or on a national level. The impact on site nonradiological waste management would also be negligible.

The estimated total quantities of solid and liquid wastes generated from activities associated with the construction of the cylinder transfer facility are shown in Table E.17. The type and quantity of solid and liquid waste expected to be generated from the operation of the cylinder transfer facility are shown in Table E.18, based on a throughput cylinder capacity of 5% of the total cylinder inventory at each site. The different types of waste generated during the operation of this facility would include LLW, low-level mixed waste (LLMW), hazardous waste, and nonhazardous waste.

TABLE E.16 Waste Generated with Activities for Cylinder Overcontainers or Standard Cylinder Preparation[a]

Site	Waste Generated: Waste Type[b]	Annual Volume (m^3/yr)	Uranium Form
Paducah	LLW (combustible solids)	12.7	UO_2F_2
Portsmouth	LLW (combustible solids)	7.0	UO_2F_2
K-25	LLW (combustible solids)	2.8	UO_2F_2

[a] Decontamination of the overcontainer surfaces was assumed to be performed at the conversion/storage facility prior to the overcontainer being sent back to the site for reuse.

[b] It was assumed that the low-level waste would be generated during removal of surface contamination and would be independent of the cylinder being standard or substandard.

TABLE E.17 Total Wastes Generated during Construction of the Cylinder Transfer Facility: Base Case

Waste Category	Quantity
Hazardous solids	38 m^3
Hazardous liquids	20,000 gal
Nonhazardous solids	
Concrete	76 m^3
Steel	30 tons
Other	612 m^3
Nonhazardous liquids	
Sanitary	3 million gal
Other	1 million gal

TABLE E.18 Estimated Annual Radioactive, Hazardous, and Nonhazardous Wastes Generated during Operation of the Cylinder Transfer Facility at the Three Sites

		Annual Volume (m^3)			
Type of Waste	Description of Waste	Paducah	Portsmouth	K-25	Contaminants
Low-Level Waste					
Combustible solids	Gloves, wipes, clothing, etc.	91	43	15	17 lb UO_2F_2
Metal, surface-contaminated	Failed equipment	12	5.3	2.2	16 lb UO_2F_2
Noncombustible compactible solids	HEPA filters	46	11	8.0	54 lb UO_2F_2
	Grouted waste	2.8	1.3	0.44	135 lb $UO_2(OH)_2$
Other	Lab packs (chemicals)	0.5	0.27	0.11	0.75 lb UO_2F_2
Low-Level Mixed Waste					
Lab packs	Chemicals	0.3	0.13	0.04	0.37 lb UO_2F_2
Inorganic process debris	Failed equipment	0.3	0.13	0.04	0.37 lb UO_2F_2
Combustible debris	Wipes, etc.	0.3	0.13	0.04	0.07 lb UO_2F_2
Hazardous Waste					
Organic liquids	Solvents, oil, paint, thinner	0.8	0.35	0.18	
Inorganic process debris	Failed equipment	1.2	0.6	0.26	1.5 lb HF, 2 lb NaOH
Combustible debris	Wipes, etc.	1.2	0.6	0.26	0.75 lb HF, 1 lb NaOH
Nonhazardous Waste					
Nonhazardous solid waste	Nonhazardous solid waste	87	46	20	
Nonhazardous liquid waste	Cooling tower blowdown process water, etc.	460	220	76	
Recyclable waste	Recyclable waste	180	85	30	

Notation: HEPA = high-efficiency particulate air (filters); HF = hydrogen fluoride; NaOH = sodium hydroxide; UO_2F_2 = uranyl fluoride; $UO_2(OH)_2$ = uranyl hydroxide.

The primary waste produced in the transfer process would be empty UF_6 cylinders and grouted waste drums. Radioactive or hazardous liquid materials would include decontamination liquids, laboratory liquid wastes, contaminated cleaning solution, lubricants, and paints. Radioactive or hazardous solid wastes would include failed process equipment, HEPA filters, laboratory wastes, wipes, rags, and operator-contaminated clothing. The LLW would be shipped off-site for disposal, and the LLMW and hazardous waste would be shipped off-site for both treatment and disposal. The total volume of crushed, empty UF_6 cylinders would be about 125,000 m^3. For the PEIS analysis, it was assumed that the treated cylinders would become part of the DOE scrap metal inventory. If a disposal decision were made, the treated cylinders could be disposed of as LLW, representing a 3% addition to the total projected DOE complex-wide LLW disposal volume.

Overall, the waste input resulting from construction and operation of a transfer facility would add about 7% to the Paducah site LLW generation and less at the Portsmouth and K-25 sites (see Appendix C, Table C.3), based on the different-sized treatment facilities at each site. The input of LLMW and nonhazardous wastes from the transfer facility would represent less than 1% of each site's LLMW or nonhazardous waste loads.

The waste input resulting from the construction and operation of the transfer facility would have minimal impact on radioactive waste management capabilities at any of the three sites. The impact on nonradiological site waste management would also be negligible. The impacts of waste resulting from the operation of the depleted UF_6 transfer facility on national waste management capabilities would be negligible.

E.3.8 Resource Requirements

Cylinder overcontainers would be constructed primarily from steel purchased from existing steel vendors. The preliminary overcontainer design requires approximately 8,000 lb (3,600 kg) of steel per overcontainer (LLNL 1997). Resources would be required only for the construction of overcontainers. No substantial resources would be required for the use of the overcontainers. Because the overcontainers would be reusable, it is estimated that the total number of overcontainers required would be approximately 581 (LLNL 1997). This total assumes a 10% contingency for spares, unforeseen delays, and the few overcontainers that might be needed at the cylinder treatment facility. The total amount of steel required for the overcontainers would be about 4,640,000 lb (2,110,000 kg). Based upon the total steel required for construction of overcontainers, no impact on local or national steel availability or production would be expected (Standard & Poor's 1996; U.S. Bureau of the Census 1996). No other materials of significant quantity would be required.

Resource needs for the cylinder transfer facility are presented in Table E.19 as utilities consumed during construction and operations at the three sites. The facility was assumed to operate 24 hours per day, 7 days per week, and 292 days per year for an 80% plant availability during operations.

The process equipment would be purchased from equipment vendors. The total quantities of commonly used construction material (i.e., steel) for equipment would be minor as compared to the quantities for construction. The primary specialty material used for equipment fabrication is at most approximately 7 tons of Monel. The material quantities required for construction and operation of the cylinder transfer facility would be minor compared to local and national supplies.

E.3.9 Land Use

No impacts to land use from cylinder overcontainer operations at any of the current cylinder storage sites would be expected. No additional land would be required, and no new construction

TABLE E.19 Resource Requirements for Construction and Operation of the Cylinder Transfer Facility

		Total Requirement		
Material/Resource	Unit	Paducah	Portsmouth	K-25
Construction				
Utilities				
Electricity	GWh	40	35	25
Solids				
Concrete	yd^3	23,000	20,000	16,000
Steel	tons	9,000	8,000	6,000
Liquids				
Fuel	million gal	1.8	1.5	1.2
Gases				
Industrial gases	gal	5,000	4,400	3,500
Specialty material (Monel)	tons	7	5	4
Operations				
Utilities				
Electricity	GWh/yr	14.6	10.8	7.1
Solids				
Cement	lb	2,700	1,600	530
Potassium hydroxide	lb	4,600	2,700	930
Liquids				
Sulfuric acid	lb/yr	2,400	1,400	470
Hydrochloric acid	lb/yr	1,900	1,300	970
Sodium hydroxide	lb/yr	1,500	1,100	770
Liquid fuel	gal/yr	6,000	5,500	4,800
Gases				
Natural gas	million scf/yr	48.5	35	26

would be necessary. Existing handling and support equipment would be utilized with no modifications required (LLNL 1997). No off-site traffic impacts would be encountered during operations because the required labor force would not appreciably affect local traffic patterns or flows.

Impacts to land use from the construction and operation of a cylinder transfer facility would be negligible and limited to temporary disruptions to contiguous land parcels and potential minor traffic disruptions from peak year construction activities. Areal requirements would be small (approximately 21 acres or less), regardless of whether or not the facility were located at one or all of the current cylinder storage sites.

The peak construction labor force for the cylinder transfer facility could result in potential off-site traffic impacts in the vicinity of the three sites, although such impacts would be negligible and would ease as construction neared completion.

E.3.10 Cultural Resources

No impacts to cultural resources would be expected at the Paducah, Portsmouth, and K-25 sites as a result of the cylinder overcontainer option for cylinder preparation. Impacts could result from the cylinder transfer option during construction of the transfer facility at one of the sites. Specific impacts cannot be determined at this time and would depend on the exact location of a facility within each site and whether eligible cultural resources existed on or near that location. Operation of the transfer facility would not affect cultural resources.

E.3.11 Environmental Justice

The analysis of human health and environmental impacts associated with the cylinder overcontainer operations (Sections E.3.1 through E.3.9) indicates that no high and adverse human health effects would be expected at any of the current cylinder storage sites during normal operations. Consequently, no particular segment of the population, including minority and low-income persons, would be disproportionately affected. The results of accident analyses for cylinder preparation did not identify high and adverse impacts to the general public (i.e., the risk of accidents, consequence times probability, was less than 1).

The construction and operation of a cylinder transfer facility at any or all of the three storage sites would not result in disproportionate effects on minority or low-income populations. The analysis of human health effects and environmental impacts associated with a cylinder transfer facility (Sections E.3.1 through E.3.9) indicates that no high and adverse human health effects or environmental impacts would be expected.

E.3.12 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur if the cylinder preparation options considered in this PEIS were implemented include impacts to the visual environment (e.g., aesthetics), recreational resources, and noise levels, as well as impacts associated with decontamination and decommissioning of the cylinder transfer facilities. These impacts, although considered, were not analyzed in detail for one or more of the following reasons:

- Consideration of these impacts would not contribute to differentiation among the alternatives and, therefore, would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS; or

- Impacts to the visual environment, recreational resources, and noise levels would be expected to stay the same as they are because cylinder preparation activities would be similar to the cylinder management activities currently ongoing at the three sites.

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APPENDIX F:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR CONVERSION OF UF_6 TO OXIDE OR METAL

CONTENTS (APPENDIX F)

CONTENTS (Cont.)

TABLES

TABLES (Cont.)

TABLES (Cont.)

FIGURE

NOTATION (APPENDIX F)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LCF	latent cancer fatality
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 μm or less
ROI	region of influence

Chemicals

AlF_3	aluminum trifluoride
CaF_2	calcium fluoride
CO	carbon monoxide
Fe	iron
HC	hydrocarbons
HF	hydrogen fluoride
HNO_3	nitric acid
Mg	magnesium
MgF_2	magnesium fluoride
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
TCE	trichloroethylene
SO_2	sulfur dioxide
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride

UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

°F	degree(s) Fahrenheit	µg	microgram(s)
Ci	curie(s)	m	meter(s)
cm	centimeter(s)	m^3	cubic meter(s)
cm^3	cubic centimeter(s)	mg	milligram(s)
d	day(s)	min	minute(s)
ft	foot (feet)	mrem	millirem(s)
ft^2	square foot (feet)	MW	megawatt(s)
g	gram(s)	MWh	megawatt hour(s)
gal	gallon(s)	pCi	picocurie(s)
gpm	gallon(s) per minute	ppm	part(s) per million
GWh	gigawatt hour(s)	psia	pound(s) per square inch absolute
ha	hectare(s)	rad	radiation absorbed dose(s)
in.	inch(es)	rem	roentgen equivalent man
kg	kilogram(s)	s	second(s)
km	kilometer(s)	scf	standard cubic foot (feet)
L	liter(s)	ton(s)	short ton(s)
lb	pound(s)	yr	year(s)

APPENDIX F:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR CONVERSION OF UF_6 TO OXIDE OR METAL

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the conversion options considered in the PEIS. The discussion provides background information for the conversion options, as well as a summary of the estimated environmental impacts associated with each option.

> **Conversion Options**
>
> Conversion of depleted UF_6 to another chemical form is required for a number of storage, use, and disposal management alternatives. The principal conversion options considered in the PEIS are as follows:
>
> **Conversion to U_3O_8.** This chemical form is a stable, low-solubility oxide considered for storage and disposal. Two different technologies were considered for conversion to U_3O_8.
>
> **Conversion to UO_2.** This stable, low-solubility oxide is considered for storage, disposal, and potential use as shielding material. Three different technologies were considered for conversion to UO_2.
>
> **Conversion to Metal.** Metallic depleted uranium is considered for use as shielding material. Two different technologies were considered for conversion to metal.

Conversion of depleted UF_6 to another chemical form is required for most alternative management strategies. Three different conversion options have been considered in the PEIS: (1) conversion to triuranium octaoxide (U_3O_8), (2) conversion to uranium dioxide (UO_2), and (3) conversion to uranium metal. The specific conversion option considered under each of the alternatives is shown in Table F.1. Because of their high chemical stability and low solubility, uranium oxides (i.e., U_3O_8 and UO_2) are considered for the storage and disposal alternatives. High-density UO_2 and uranium metal are considered for the use alternatives (e.g., spent nuclear fuel radiation shielding applications). Other details concerning the characteristics of the different chemical forms of uranium are given in Appendix A.

Conversion of depleted UF_6 to another chemical form would take place at a stand-alone industrial plant dedicated to the conversion process. A representative conversion plant layout is shown in Figure F.1; the actual plant layout would depend on the specific conversion option and technology selected, as well as on certain site characteristics. In general, the plant would be capable of receiving depleted UF_6 cylinders on trucks or railcars, temporarily storing a small inventory of

TABLE F.1 Summary of the Conversion Options Considered for Each Programmatic Management Alternative

	Option Considered for Management Alternative[a]					
		Long-Term Storage		Use		
Option	No Action	UF_6	Oxide	Uranium Oxide	Uranium Metal	Disposal
Conversion to U_3O_8	–	–	X	–	–	X
Conversion to UO_2	–	–	X	X	–	X
Conversion to metal	–	–	–	–	X	–

[a] X = option considered; – = option not considered.

full cylinders, processing the depleted UF_6 to another chemical form, and storing the converted uranium product and any other products until shipment off-site. The empty cylinders would be stored until transfer to a cylinder treatment facility, which is assumed to be located at the conversion plant site. It is estimated that a typical conversion plant would cover an area of approximately 20 acres (8 ha) (Lawrence Livermore National Laboratory [LLNL] 1997).

In general, potential environmental impacts would occur (1) during construction of a conversion facility, (2) during operations of the facility, and (3) during postulated accidents. The potential impacts associated with facility construction would result from typical land-clearing and construction activities. Potential impacts during operations would occur primarily to workers during handling operations and to the public as a result of routine releases of small amounts of contaminants through exhaust stacks and treated liquid effluent discharges. In addition, potential impacts to workers and the public from processing or storage might occur as a result of accidents that release hazardous materials.

The environmental impacts from the conversion options were evaluated based on the information described in the engineering analysis report (LLNL 1997). For each of the three conversion options (conversion to U_3O_8, UO_2, or metal), the engineering analysis report provides preconceptual facility design data, including descriptions of facility layouts; resource requirements; estimates of effluents, wastes, and emissions; and estimates of potential accident scenarios. Within each conversion option, several technologies or chemical processes that could be used to produce the same uranium end product are described (two are considered for conversion to U_3O_8, three for conversion to UO_2, and two for conversion to metal). Some of these technologies have not been demonstrated on a commercial scale but were considered to provide an estimate of the range of the

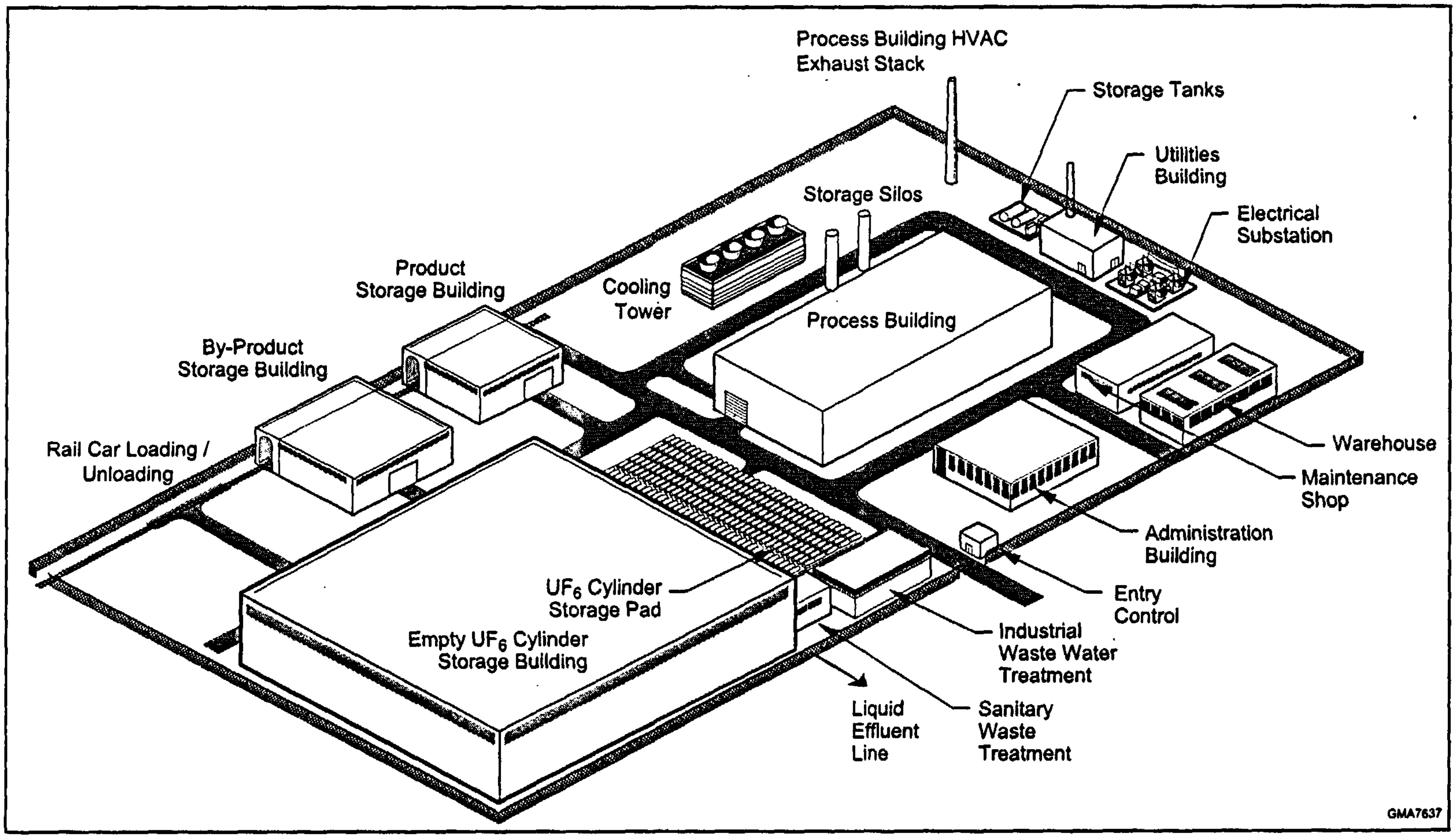

FIGURE F.1 Representative Site Layout for a Conversion Facility

environmental impacts that might be associated with each of the conversion options. All facility designs were based on a single plant sized to process the entire inventory of DOE-generated depleted UF_6 cylinders over a 20-year period (approximately 2,300 cylinders per year).

F.1 SUMMARY OF CONVERSION OPTION IMPACTS

A summary of the potential environmental impacts associated with the conversion options is provided in this section. These potential impacts are not site-specific because the location of a conversion facility, if required at all, would not be decided until some time in the future. For assessment purposes, the environmental impacts were determined for a range of environmental conditions represented by those at the three current depleted UF_6 storage sites.

The potential environmental impacts for the three conversion options are compared in Table F.2. For each conversion option, the potential environmental impacts are presented as a range within each area of impact. This range is intended to provide a reasonable estimate of the magnitude of impacts, taking into account the uncertainty relative to the specific technologies and sites that could ultimately be selected for conversion. The range of impacts results from two factors: (1) fundamental differences among the technologies within each conversion option; and (2) differences in the conditions at the three representative sites that were evaluated. A more detailed assessment of specific technologies and site conditions will be conducted, as appropriate, as part of the second phase (tier) of the programmatic *National Environmental Policy Act* (NEPA) approach. Additional discussion and details related to the assessment methodologies and results for individual areas of impact are provided in the remaining sections of this appendix.

F.2 DESCRIPTION OF OPTIONS

This section provides a brief summary of the different conversion options considered in the assessment of conversion impacts (Table F.3). The information is based on preconceptual design data provided in the engineering analysis report (LLNL 1997). The engineering analysis report includes much more detailed information, such as descriptions of facility layouts; resource requirements; estimates of effluents, wastes, and emissions; and estimates of potential accident scenarios.

All of the conversion options would involve the removal of depleted UF_6 from the storage cylinders, resulting in a large number of empty cylinders. These empty cylinders would contain approximately 22 lb (10 kg) of depleted UF_6 (Charles et al. 1991), called "heels." For assessment purposes, it has been assumed that a cylinder treatment facility would be constructed to wash the empty cylinders. This facility has been assumed to be an independent, or "stand-alone," facility, although it could be integrated directly into the design of the conversion plant. The facility would be co-located with the conversion plant.

TABLE F.2 Summary of Conversion Option Impacts

Impacts from Conversion to U_3O_8	Impacts from Conversion to UO_2	Impacts from Conversion to Metal	Impacts from Cylinder Treatment[a]
Human Health – Normal Operations: Radiological			
Involved Workers: Total collective dose: 820 person-rem	**Involved Workers:** Total collective dose: 980 – 1,100 person-rem	**Involved Workers:** Total collective dose: 650 – 1,300 person-rem	**Involved Workers:** Total collective dose: 320 person-rem
Total number of LCFs: 0.3 LCF	Total number of LCFs: 0.4 LCF	Total number of LCFs: 0.3 – 0.5 LCF	Total number of LCFs: 0.1 LCF
Noninvolved Workers: Annual dose to MEI: $1.6 \times 10^{-3} – 5.8 \times 10^{-3}$ mrem/yr	**Noninvolved Workers:** Annual dose to MEI: $3.2 \times 10^{-3} – 2.2 \times 10^{-2}$ mrem/yr	**Noninvolved Workers:** Annual dose to MEI: $6.8 \times 10^{-4} – 1.7 \times 10^{-2}$ mrem/yr	**Noninvolved Workers:** Annual dose to MEI: $4.9 \times 10^{-6} – 1.8 \times 10^{-5}$ mrem/yr
Annual cancer risk to MEI: $6 \times 10^{-10} – 2 \times 10^{-9}$ per year	Annual cancer risk to MEI: $1 \times 10^{-9} – 9 \times 10^{-9}$ per year	Annual cancer risk to MEI: $3 \times 10^{-10} – 7 \times 10^{-9}$ per year	Annual cancer risk to MEI: $2 \times 10^{-12} – 7 \times 10^{-12}$ per year
Total collective dose: 0.043 – 0.09 person-rem	Total collective dose: 0.084 – 0.34 person-rem	Total collective dose: 0.018 – 0.27 person-rem	Total collective dose: $1.3 \times 10^{-4} – 2.7 \times 10^{-4}$ person-rem
Total number of LCFs: $2 \times 10^{-5} – 4 \times 10^{-5}$ LCF	Total number of LCFs: $3 \times 10^{-5} – 1 \times 10^{-4}$ LCF	Total number of LCFs: $7 \times 10^{-6} – 1 \times 10^{-4}$ LCF	Total number of LCFs: $5 \times 10^{-8} – 1 \times 10^{-7}$ LCF
General Public: Annual dose to MEI: $4.9 \times 10^{-3} – 8.8 \times 10^{-3}$ mrem/yr	**General Public:** Annual dose to MEI: $9.7 \times 10^{-3} – 3.3 \times 10^{-2}$ mrem/yr	**General Public:** Annual dose to MEI: $2.1 \times 10^{-3} – 2.6 \times 10^{-2}$ mrem/yr	**General Public:** Annual dose to MEI: $1.5 \times 10^{-5} – 2.7 \times 10^{-5}$ mrem/yr
Annual cancer risk to MEI: $2 \times 10^{-9} – 4 \times 10^{-9}$ per year	Annual cancer risk to MEI: $5 \times 10^{-9} – 2 \times 10^{-8}$ per year	Annual cancer risk to MEI: $1 \times 10^{-9} – 1 \times 10^{-8}$ per year	Annual cancer risk to MEI: $8 \times 10^{-12} – 1 \times 10^{-11}$ per year
Total collective dose to population within 50 miles: 0.79 – 2.7 person-rem	Total collective dose to population within 50 miles: 1.6 – 10 person-rem	Total collective dose to population within 50 miles: 0.34 – 8.0 person-rem	Total collective dose to population within 50 miles: 0.0024 – 0.0082 person-rem
Total number of LCFs in population within 50 miles: 0.0004 – 0.001 LCF	Total number of LCFs in population within 50 miles: 0.0008 – 0.005 LCF	Total number of LCFs in population within 50 miles: 0.0002 – 0.004 LCF	Total number of LCFs in population within 50 miles: $1 \times 10^{-6} – 4 \times 10^{-6}$ LCF

TABLE F.2 (Cont.)

Impacts from Conversion to U_3O_8	Impacts from Conversion to UO_2	Impacts from Conversion to Metal	Impacts from Cylinder Treatment[a]
Human Health – Normal Operations: Chemical			
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts	**General Public:** No impacts
Human Health – Accidents: Radiological			
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 9.2 rem Risk of LCF to MEI: 4×10^{-3} Collective dose: 840 person-rem Number of LCFs: 0.3	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 2.3 rem Risk of LCF to MEI: 9×10^{-4} Collective dose: 210 person-rem Number of LCFs: 0.08	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 8×10^{-6} Collective dose: 7.5 person-rem Number of LCFs: 3×10^{-3}	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.43 rem Risk of LCF to MEI: 2×10^{-4} Collective dose: 38 person-rem Number of LCFs: 0.02
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.27 rem Risk of LCF to MEI: 1×10^{-4} Collective dose to population within 50 miles: 20 person-rem Number of LCFs in population within 50 miles: 0.01 LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.068 rem Risk of LCF to MEI: 3×10^{-5} Collective dose to population within 50 miles: 5.1 person-rem Number of LCFs in population within 50 miles: 0.003 LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem Risk of LCF to MEI: 7×10^{-6} Collective dose to population within 50 miles: 56 person-rem Number of LCFs in population within 50 miles: 0.03 LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.013 rem Risk of LCF to MEI: 7×10^{-6} Collective dose to population within 50 miles: 2.5 person-rem Number of LCFs in population within 50 miles: 0.001 LCF

TABLE F.2 (Cont.)

Impacts from Conversion to U_3O_8	Impacts from Conversion to UO_2	Impacts from Conversion to Metal	Impacts from Cylinder Treatment[a]
	Human Health – Accidents: Chemical		
Bounding accident frequency: less than once in 1 million years	Bounding accident frequency: less than once in 1 million years	Bounding accident frequency: less than once in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 1,100 persons	Number of persons with potential for adverse effects: 1,100 persons	Number of persons with potential for adverse effects: 1,100 persons	Number of persons with potential for adverse effects: 1 person
Number of persons with potential for irreversible adverse effects (bounding accident frequency: 1 in 10,000 years to 1 in 1 million years): 440 persons	Number of persons with potential for irreversible adverse effects (bounding accident frequency: 1 in 10,000 years to 1 in 1 million years): 440 persons	Number of persons with potential for irreversible adverse effects (bounding accident frequency: 1 in 10,000 years to 1 in 1 million years): 440 persons	Number of persons with potential for irreversible adverse effects: 0 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 41,000 persons	Number of persons with potential for adverse effects: 41,000 persons	Number of persons with potential for adverse effects: 41,000 persons	Number of persons with potential for adverse effects: 0 persons
Number of persons with potential for irreversible adverse effects: 1,700 persons	Number of persons with potential for irreversible adverse effects: 1,700 persons	Number of persons with potential for irreversible adverse effects: 1,700 persons	Number of persons with potential for irreversible adverse effects: 0 persons
	Human Health — Accidents: Physical Hazards		
Construction and Operations: **All Workers:** Less than 1 (0.35) fatality, approximately 290 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.59) fatality, approximately 490 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.55) fatality, approximately 490 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.19) fatality, approximately 170 injuries

TABLE F.2 (Cont.)

Impacts from Conversion to U_3O_8	Impacts from Conversion to UO_2	Impacts from Conversion to Metal	Impacts from Cylinder Treatment[a]
		Air Quality	
Construction: 24-hour PM_{10} concentration potentially as large as 65% of standard. Concentrations of other criteria pollutants all below 15% of respective standards.	**Construction:** 24-hour PM_{10} concentration potentially as large as 90% of standard. Concentrations of other criteria pollutants all below 30% of respective standards.	**Construction:** 24-hour PM_{10} concentration potentially as large as 90% of standard. Concentrations of other criteria pollutants all below 20% of respective standards.	**Construction:** 24-hour PM_{10} concentration potentially as large as 25% of standard. Concentrations of other criteria pollutants all below 10% of respective standards.
Operations: 8-hour CO concentration potentially as large as 3% of standard.	**Operations:** 8-hour CO concentration potentially as large as 5% of standard.	**Operations:** 8-hour CO concentration potentially as large as 5% of standard.	**Operations:** Concentrations of all criteria pollutants below 0.06% of respective standards.
		Water	
Construction: None to negligible physical impacts; concentrations less than applicable standards	**Construction:** None to negligible physical impacts; concentrations less than applicable standards	**Construction:** None to negligible physical impacts; concentrations less than applicable standards	**Construction:** None to negligible physical impacts; concentrations less than applicable standards
Operations: None to negligible physical impacts to surface water and groundwater; concentrations less than applicable standards	**Operations:** None to negligible physical impacts to surface water and groundwater; concentrations less than applicable standards	**Operations:** None to negligible physical impacts to surface water and groundwater; concentrations less than applicable standards	**Operations:** None to negligible physical impacts to surface water and groundwater; concentrations less than applicable standards
		Soil	
Construction: None to negligible impacts	**Construction:** None to negligible impacts	**Construction:** None to negligible impacts	**Construction:** None to negligible impacts
Operations: None to negligible physical impacts; concentrations less than applicable guidelines	**Operations:** None to negligible physical impacts; concentrations less than applicable guidelines	**Operations:** None to negligible physical impacts; concentrations less than applicable guidelines	**Operations:** None to negligible physical impacts; concentrations less than applicable guidelines

TABLE F.2 (Cont.)

Impacts from Conversion to U_3O_8	Impacts from Conversion to UO_2	Impacts from Conversion to Metal	Impacts from Cylinder Treatment[a]
		Socioeconomics	
Construction: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Negligible to low impacts to ROI employment and population growth rates and to public finances; potential moderate impacts to vacant housing	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.
Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Negligible to low impacts to ROI employment and population growth rates and to public finances; potential moderate impacts to vacant housing	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances.
		Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife
Operations: Negligible impacts	**Operations:** Negligible impacts	**Operations:** Negligible impacts	**Operations:** Negligible impacts
		Waste Management	
Potential moderate impacts to site, regional, or national waste management operations	Potential moderate impacts to site, regional, or national waste management operations	Potential moderate impacts to site, regional, or national waste management operations	Potential moderate impacts to national waste management operations

TABLE F.2 (Cont.)

Impacts from Conversion to U_3O_8	Impacts from Conversion to UO_2	Impacts from Conversion to Metal	Impacts from Cylinder Treatment[a]
		Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale	No impacts from resource requirements (such as electricity or materials) on the local or national scale
		Land Use[b]	
Construction: Use of approximately 20 acres; negligible impacts	**Construction:** Use of approximately 22 to 31 acres; negligible impacts	**Construction:** Use of approximately 23 to 26 acres; negligible impacts	**Construction:** Use of approximately 9 acres; negligible impacts
Operations: Use of approximately 13 acres; negligible impacts	**Operations:** Use of approximately 14 to 20 acres; negligible impacts	**Operations:** Use of approximately 15 to 16 acres; negligible impacts	**Operations:** Use of approximately 5 acres; negligible impacts

[a] These impacts must be added to those for each of the conversion options.

[b] Land-use acreages given as maximum for a single site or facility. Conversion facilities would also need to establish protective action distances encompassing about 960 acres around the facility.

Notation: CO = carbon monoxide; LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 μm or less; *ROI* = region of influence.

TABLE F.3 Summary of Technologies Considered under Each Conversion Option

Conversion Option	Technologies
Conversion to U_3O_8	- Defluorination with anhydrous HF production - Defluorination with HF neutralization
Conversion to UO_2	- Dry process with anhydrous HF production - Dry process with HF neutralization - Gelation process
Conversion to metal	- Batch metallothermic reduction - Continuous metallothermic reduction

Following removal of the depleted UF_6, the emptied cylinders containing "heels" would be stored for about 3 months to allow the level of radioactivity associated with the decay products of uranium that remained after UF_6 withdrawal to decrease to acceptable levels. Subsequently, in the proposed cylinder treatment facility, the emptied cylinders are first washed with water and the resulting aqueous wash solution is evaporated and converted to solid U_3O_8 and hydrogen fluoride (HF). The U_3O_8 would be packaged and sent either for disposal or storage. The HF would be neutralized to calcium fluoride (CaF_2) and separately packaged for disposal or sale.

It was assumed that the treated cylinders with a very low residual radiation level would become part of the DOE scrap metal inventory. A report by Nieves et al. (1997) analyzed the potential health and cost impacts associated with various options for the empty cylinders after treatment, including recycle into low-level radioactive waste (LLW) disposal containers, reuse as LLW containers, free release for remelting, and disposal (i.e., burial) as LLW. Health endpoints assessed included chemical risks, radiation risks, and trauma risks. The estimated total health risks over 20 years of processing ranged from 0.1 to 0.8 total fatality for the various options. The potential health impacts were similar for each of the options; however, the disposal option was considered to have the greatest adverse environmental impacts because it would require land allocations and removal of the metal mass from any further usefulness.

F.2.1 Conversion to U_3O_8

A "dry" process, referred to as defluorination, is well established and currently used by industry. It is also practiced on a large-scale industrial basis by Cogema in France. In this process, UF_6 is chemically decomposed with steam and heat to produce U_3O_8 and concentrated HF. The U_3O_8 would then be compacted to achieve a bulk density of about 3 g/cm^3 prior to storage or disposal.

Two technologies were considered for management of the HF following conversion of UF_6 to U_3O_8. The first process would upgrade the concentrated HF to anhydrous HF for sale. Anhydrous HF is a valuable product; one potential use for HF is in the production of UF_6 from natural uranium ore for feedstock to the gaseous diffusion process. The second process would neutralize the HF to CaF_2 for disposal or sale, depending on whether the CaF_2 with trace amounts of uranium could be marketed.

Because of the considerable market for anhydrous HF, the technology of defluorination with anhydrous HF production would minimize waste and increase product value. However, the handling, storage, and transportation of large quantities of anhydrous HF pose a potential hazard to both workers and the public. During the conversion process, the HF would be upgraded to anhydrous HF by distillation, a common industrial process. Based on historical experience, it is anticipated that the anhydrous HF would contain only trace amounts of depleted uranium (less than 1 ppm, or 0.4 pCi/g) (LLNL 1997). Thus, it was assumed that the anhydrous HF could be sold commercially for unrestricted use.

The process of HF neutralization with lime would convert the concentrated HF to CaF_2 for disposal or possible sale. This step would avoid the potential hazards associated with the processing, general handling, storage, and transportation of large quantities of anhydrous HF. However, the value of CaF_2 is significantly less than that of anhydrous HF, and large quantities of lime are required for neutralization, which would add to the cost of the neutralization option. It is also unknown whether the CaF_2 produced would be sold, disposed of as nonhazardous solid waste, or disposed of as LLW. If disposal were required, there could be moderate impacts to waste management (see Section F.3.7).

F.2.2 Conversion to UO_2

The conversion of UF_6 to UO_2 is used in the nuclear fuel fabrication industry. The UF_6 is converted to a low-density UO_2 powder by either a "wet" or "dry" process. "Wet" processes are based upon separation of solid UO_2 from an aqueous solution, whereas "dry" processes are based upon decomposing and reducing the UF_6. The resulting powder is pressed into a pellet under high pressure, and the pellet is sintered (agglomerated) at high temperatures to yield a dense solid. Depending on the shape, size, and size distribution, the bulk density of UO_2 will generally be 6 to 9 g/cm^3.

Three technologies were considered for the conversion of UF_6 to UO_2. A generic industrial dry process with conversion to produce centimeter-sized pellets is the basis for the first two technologies. The first process would upgrade the concentrated HF to anhydrous HF for sale, similar to the U_3O_8 process. The second process would neutralize the HF to CaF_2 for disposal or sale. The third process is a "wet" process, based on pilot-scale studies, and is referred to as the gelation process.

In the dry process, gaseous UF_6 would be chemically reacted with steam to produce solid uranyl fluoride (UO_2F_2) and HF. The UO_2F_2 would then be converted to UO_2 powder through a combination of chemical reactions. Using standard physical treatment operations (milling, compacting, and screening) and the addition of a dry lubricant, the UO_2 powder would be pressed into dense pellets with a bulk density of about 6 g/cm^3. The HF would be upgraded to anhydrous HF for commercial resale, as described in Section F.2.1. In the other dry process, the HF would be neutralized to CaF_2 rather than upgraded to anhydrous HF.

In the gelation process, small, dense spheres of UO_2 would be produced through a combination of chemical processes beginning with the conversion of UF_6 to UO_2F_2 and anhydrous HF. The solid UO_2F_2 would then be reacted with steam to produce U_3O_8 and additional anhydrous HF. The U_3O_8 would be dissolved in nitric acid, mixed with other chemicals, and chilled to form a feed broth. This broth would be formed into droplets and fed into a column of hot chlorinated hydrocarbon liquid. Once these droplets formed into spheres, they would be removed from the hot liquid and washed. The droplets would then be dried and converted by heating to dense uranium oxide. The final sintered uranium dioxide spheres are expected to have a density of about 95% or greater of the theoretical maximum density of uranium dioxide, resulting in a bulk density of about 9 g/cm^3. The gelation process has not been demonstrated on a commercial scale.

F.2.3 Conversion to Metal

The conversion of UF_6 to uranium metal would use a commercial process called metallothermic reduction. During this process, UF_6 would react with both hydrogen and magnesium metal to produce uranium metal, anhydrous HF, and magnesium fluoride ($MgFl_2$; slag). Two technologies were considered: a batch reduction process, which is the method used to date, and a continuous reduction process, which is under development and has not been demonstrated on a commercial scale.

In the batch metallothermic reduction process, the UF_6 would be mixed with hydrogen gas in a vertical reaction vessel to form uranium tetrafluoride (UF_4) and HF. The anhydrous HF would be recovered and stored for sale. The UF_4 powder and an excess of magnesium would be contained in a sealed metal vessel and preheated. Once initiated, the reaction would produce molten uranium metal (collecting at the bottom of the reactor) and less dense molten MgF_2 slag. The cycle time per batch (about 12 hours total) would be dominated by the heating and cooling periods. A large number of reactors would be required because of the long cycle time. The slag would be ground, screened, and prepared for disposal. Any metal pellets would be recovered for recycle.

In the continuous metallothermic reduction process, the UF_6 would be mixed with hydrogen gas in a vertical reaction vessel to form UF_4 and HF. The anhydrous HF would be recovered and stored for sale. A mixture of UF_4, magnesium (Mg), iron (Fe), and salt would be continuously fed into the top of a heated reactor. The more dense molten uranium/iron compound would settle to the bottom of the reactor where it would be continuously withdrawn. The lower density MgF_2/salt mixture would float on top and be separately withdrawn. The molten uranium/iron compound would then be cast into ingots or the end-product form if the manufacturing function was integrated into the conversion facility. The molten salt mixture would be cooled and ground and the water-soluble salt dissolved. After evaporation and drying, the salt would be recycled to the reactor. The insoluble MgF_2 would be drummed for disposal. The annual throughput of the continuous metallothermic reduction reactor would be greater than a batch reactor, requiring fewer reactors.

Neutralization of HF to CaF_2 was not explicitly analyzed in the engineering analysis report for the conversion to metal options (LLNL 1997). However, the process could be implemented and would produce approximately one-third as much CaF_2 as would be produced under the conversion to oxide with neutralization options.

F.2.4 Conversion Technologies and Chemical Forms Considered But Not Analyzed in Detail

The conversion technologies analyzed in the engineering analysis report (LLNL 1997) and the PEIS are those with a sufficient technical basis to carry out preconceptual designs. A number of other promising conversion technologies were considered, but, with minor exceptions, these are in the early stages of conceptualization or development. These options are also discussed in the engineering analysis report (LLNL 1997).

For conversion to an oxide form, technologies considered but not analyzed in detail include a molten metal catalyzed process; the Cameco process (patent pending), which uses a different chemical process than steam hydrolysis/pyrolysis; a conversion process that produces a by-product of aluminum trifluoride (AlF_3); and a defluorination process that results in the production of hydrofluorocarbons. For conversion to metal, a plasma dissociation process was considered but not analyzed in detail.

F.3 IMPACTS OF OPTIONS

This section provides a summary of the potential environmental impacts associated with the conversion options, including impacts from construction and facility operations. For each area of impact, a description of the assessment methodology (including models) is provided in Appendix C.

The environmental impacts from the conversion options were evaluated based on the information described in the engineering analysis report (LLNL 1997). The following general assumptions apply to all conversion facility operations:

- All facility designs were based on a single conversion plant sized to process the entire inventory of DOE-generated depleted UF_6 cylinders over a 20-year period (approximately 2,300 cylinders per year).

- The conversion plant was assumed to operate 24 hours per day, 7 days per week, 52 weeks per year, with 20% down-time.

- A "stand-alone" cylinder treatment facility (for empty cylinders) is collocated with the conversion plant.

The location of a conversion facility at one of the three current storage sites, if required at all, would not be decided until some time in the future. Instead, for each conversion option, the environmental impacts were calculated separately for a single hypothetical facility located at each of the three current depleted UF_6 storage sites. The three current storage sites were used to provide a reasonable range of environmental conditions. A more detailed assessment of site considerations would be addressed, as appropriate, as part of the second phase (tier) of the programmatic NEPA approach.

For each conversion option, the potential environmental impacts are presented as a range within each area of impact. This range is intended to provide a reasonable estimate of the magnitude of impacts, taking into account the uncertainty relative to the specific technologies and sites that would ultimately be selected for conversion. The range of impacts results from two factors: (1) fundamental differences among the technologies within each conversion option and (2) differences in the site conditions.

F.3.1 Human Health — Normal Operations

F.3.1.1 Radiological Impacts

Radiological impacts to involved workers during normal operations at conversion facilities would result primarily from external radiation from the handling of depleted uranium materials. Impacts to noninvolved workers and members of the public would result primarily from trace amounts of uranium compounds released to the environment. Detailed discussions of the methodologies used in radiological impact analysis are provided in Appendix C and in Cheng et al. (1997).

F.3.1.1.1 Conversion to U_3O_8

Conversion to U_3O_8 would result in average radiation exposure of about 300 mrem/yr to involved workers and less than 0.01 mrem/yr to noninvolved workers and members of the public. Radiation doses and cancer risks associated with normal operations of the U_3O_8 conversion facilities are listed in Tables F.4 and F.5, respectively. The two conversion technologies evaluated are described in Section F.2.1. Due to the similarity of the conversion processes, the airborne emission rates of uranium compounds and the material handling activities are expected to vary only slightly from each other, resulting in similar radiological impacts.

Involved Workers. Radiation exposures for the involved workers are estimated according to the descriptions of material handling activities provided in the engineering analysis report (LLNL 1997). Due to the preliminary nature of each facility design, the estimated radiation doses are subject to a large degree of uncertainty. The results presented in this appendix should be used only for purposes of comparison among different technologies. Radiation exposure of involved workers would be monitored by a dosimetry program and maintained below regulatory limits.

The collective dose for involved workers is estimated to be about 41 person-rem/yr for 135 workers for the U_3O_8 conversion processes. This would result in about 0.02 excess latent cancer fatalities (LCFs) per year (or about 2 LCFs over a 100-year period) among the involved workers. If evenly distributed among involved workers, the average individual dose would be approximately 300 mrem/yr, well below the regulatory limit of 5,000 mrem/yr for workers (10 *Code of Federal Regulations* [CFR] Part 835). This corresponds to an average cancer risk of about 1×10^{-4} per year (1 chance in 10,000 of developing 1 LCF per year).

Noninvolved Workers. Estimated doses and health risks are much lower for noninvolved workers than for involved workers. Inhalation of U_3O_8 particulates accounts for more than 99.9% of the radiological exposures for noninvolved workers. The radiation dose (risk of an LCF) to a maximally exposed noninvolved worker would range from 1.6×10^{-3} mrem/yr (6×10^{-10} per year) to 5.8×10^{-3} mrem/yr (2×10^{-9} per year), which is a very small fraction (less than 1 in 1,000) of the maximally allowable dose limit (10 mrem/yr) from airborne emissions (40 CFR Part 61). The population of noninvolved workers would vary from site to site. For representative noninvolved worker population sizes ranging from 2,000 to 3,500, the resulting collective dose would range from 0.0021 to 0.0045 person-rem/yr.

General Public. The locations of the maximally exposed individual (MEI) for the general public are either at or near the site boundary. Although other exposure pathways are also considered, inhalation exposure accounts for more than 95% of the total dose. The radiation dose for the MEI would be negligible, ranging from 0.0049 to 0.0088 mrem/yr, compared with the dose limit of 10 mrem/yr from airborne emissions. The potential radiation dose resulting from drinking

TABLE F.4 Radiological Doses from Conversion/Treatment Options under Normal Operations[a]

Option	Dose to Receptor: Involved Workers[b] Average Dose (mrem/yr)	Involved Workers[b] Collective Dose (person-rem/yr)	Noninvolved Workers[c] MEI Dose[d] (mrem/yr)	Noninvolved Workers[c] Collective Dose (person-rem/yr)	General Public MEI Dose[e] (mrem/yr)	General Public Collective Dose[f] (person-rem/yr)
Conversion to U_3O_8	300	41	1.6×10^{-3} – 5.8×10^{-3}	2.1×10^{-3} – 4.5×10^{-3}	4.9×10^{-3} – 8.8×10^{-3}	3.9×10^{-2} – 1.4×10^{-1}
Conversion to UO_2	180 – 340	49 – 54	3.2×10^{-3} – 2.2×10^{-2}	4.2×10^{-3} – 1.7×10^{-2}	9.7×10^{-3} – 3.3×10^{-2}	7.8×10^{-2} – 5.1×10^{-1}
Conversion to metal	230 – 240	33 – 67	6.8×10^{-4} – 1.7×10^{-2}	9.0×10^{-4} – 1.3×10^{-2}	2.1×10^{-3} – 2.6×10^{-2}	1.7×10^{-2} – 4.0×10^{-1}
Cylinder treatment	160	16	4.9×10^{-6} – 1.8×10^{-5}	6.5×10^{-6} – 1.4×10^{-5}	1.5×10^{-5} – 2.7×10^{-5}	1.2×10^{-4} – 4.1×10^{-4}

[a] Impacts are reported as ranges, which result from variations in the three representative facility locations and the different conversion technologies within each option.

[b] Involved workers are those workers directly involved with the handling of radioactive materials. Calculation results are presented as average individual dose and collective dose for the worker population. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[c] Noninvolved workers include individuals who work at the facility but are not directly involved in handling materials and individuals who work on-site but not within the facility. The population size of noninvolved workers ranges from 2,000 to 3,500 for all options.

[d] The MEI for the noninvolved workers was assumed to be located on-site 100 m or more from the release point at the location that would result in the largest dose, which includes doses from inhalation, external radiation, and incidental soil ingestion.

[e] The MEI for the general public was assumed to be located off-site at the point that would result in the largest dose from exposures through inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

[f] Collective dose was estimated for the populations (ranging from 500,000 to 880,000 persons) within a radius of 50 miles (80 km) around the three representative sites. The exposure pathways considered are inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

TABLE F.5 Latent Cancer Risks from Conversion/Treatment Options under Normal Operations[a]

	Latent Cancer Risk to Receptor					
	Involved Workers[b]		Noninvolved Workers[c]		General Public	
Option	Average Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[d] (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Conversion to U_3O_8	1×10^{-4}	2×10^{-2}	6×10^{-10} – 2×10^{-9}	9×10^{-7} – 2×10^{-6}	2×10^{-9} – 4×10^{-9}	2×10^{-5} – 7×10^{-5}
Conversion to UO_2	7×10^{-5} – 1×10^{-4}	2×10^{-2}	1×10^{-9} – 9×10^{-9}	2×10^{-6} – 7×10^{-6}	5×10^{-9} – 2×10^{-8}	4×10^{-5} – 3×10^{-4}
Conversion to metal	9×10^{-5} – 1×10^{-4}	1×10^{-2} – 3×10^{-2}	3×10^{-10} – 7×10^{-9}	4×10^{-7} – 5×10^{-6}	1×10^{-9} – 1×10^{-8}	9×10^{-6} – 2×10^{-4}
Cylinder treatment	6×10^{-5}	6×10^{-3}	2×10^{-12} – 7×10^{-12}	3×10^{-9} – 5×10^{-9}	8×10^{-12} – 1×10^{-11}	6×10^{-8} – 2×10^{-7}

[a] Impacts are reported as ranges, which result from variations in the three representative facility locations and the different conversion technologies within each option.

[b] Involved workers are those workers directly involved with the handling of radioactive materials. Calculation results are presented as average individual risk and collective risk for the worker population.

[c] Noninvolved workers include individuals who work at the facility but are not directly involved in handling materials and individuals who work on-site but not within the facility. The population size of noninvolved workers ranges from 2,000 to 3,500 for all options.

[d] The MEI for the noninvolved workers was assumed to be located on-site 100 m or more from the release point at the location that would result in the largest risk, which includes risks from inhalation, external radiation, and incidental soil ingestion.

[e] The MEI for the general public was assumed to be located off-site at the point that would result in the largest risk from exposures through inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

[f] Collective risk was estimated for the populations (ranging from 500,000 to 880,000 persons) within a radius of 50 miles (80 km) around the three representative sites. The exposure pathways considered are inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil.

contaminated surface water would be two orders of magnitude less than that from exposure to airborne emissions.

For a location with an off-site population ranging from 500,000 to 880,000 persons within a 50-mile (80-km) distance from the site boundary, the collective dose would range from 0.039 to 0.14 person-rem/yr, which corresponds to about 2×10^{-5} to 7×10^{-5} LCF per year (less than 1 chance in 10,000 of 1 LCF per year in the population).

F.3.1.1.2 Conversion to UO_2

Conversion to UO_2 would result in average radiation exposure of less than 340 mrem/yr to involved workers and less than 0.04 mrem/yr to noninvolved workers and members of the public, similar to those for conversion to U_3O_8. The radiation doses and cancer risks associated with normal operations of the UO_2 conversion facilities are listed in Tables F.4 and F.5, respectively.

Involved Workers. The estimated collective dose for involved workers ranges from 49 to 54 person-rem/yr, slightly greater than conversion to U_3O_8. This would result in approximately 0.02 excess cancer fatality per year (2 LCFs over a 100-year period). If evenly distributed among involved workers (about 160 to 270 workers), the average individual dose would range from about 180 to 340 mrem/yr, well below the annual worker dose limit of 5,000 mrem/yr. This corresponds to an average cancer risk of 7×10^{-5} to 1×10^{-4} per year (less than 1 chance in 10,000 of developing 1 LCF per year).

Noninvolved Workers. The doses to noninvolved workers are similar to but slightly higher than those for conversion to U_3O_8. The dose to the MEI would range from 0.0032 to 0.022 mrem/yr, which is negligible compared with the dose limit of 10 mrem/yr for airborne emissions. For representative population sizes ranging from 2,000 to 3,500, the collective dose would range from 0.0042 to 0.017 person-rem/yr. The estimated number of potential LCFs would be less than 0.00001 per year.

General Public. The estimated radiation dose to the MEI for the general public would be slightly higher than that from conversion to U_3O_8, ranging from 0.0097 to 0.033 mrem/yr. These values are well below the radiation dose limit of 10 mrem/yr set for airborne emissions. The radiation dose from drinking contaminated surface water would be very small compared with the dose from airborne emissions. The collective dose for a population of 500,000 to 880,000 persons would range from 0.078 to 0.51 person-rem/yr. This would correspond to 4×10^{-5} to 3×10^{-4} LCF per year among the population (less than 1 chance in 3,000 of 1 LCF per year).

F.3.1.1.3 Conversion to Metal

Conversion to uranium metal would result in average exposure of less than 240 mrem/yr to involved workers and less than 0.03 mrem/yr to noninvolved workers and members of the public. The radiological impacts and cancer risks from operations of the metal conversion facilities are shown in Tables F.4 and F.5, respectively.

Involved Workers. The collective dose to involved workers would range from 33 to 67 person-rem/yr, similar to conversion to U_3O_8 and conversion to UO_2. The corresponding number of LCFs would range from 0.01 to 0.03 per year (1 to 3 LCFs over a 100-year period) among a worker population of approximately 140 to 270. If evenly distributed among workers, the average annual worker dose would be about 240 mrem/yr, which is well below the regulatory limit of 5,000 mrem/yr. The corresponding cancer risk is 0.0001 per year (less than 1 chance in 10,000 of developing 1 LCF per year).

Noninvolved Workers. The radiation dose to noninvolved workers would be similar to those for conversion to U_3O_8 and conversion to UO_2 and would be negligible compared with the regulatory dose limit of 10 mrem/yr. The collective dose would range from 0.0009 to 0.013 person-rem/yr for 2,000 to 3,500 workers.

General Public. The radiation dose for the MEI of the general public would range from 0.0021 to 0.026 mrem/yr, which corresponds to a cancer risk of 1×10^{-9} to 1×10^{-8} per year (less than 1 chance in 100 million of developing 1 LCF per year). The radiation dose from drinking contaminated surface water would be very small compared with the dose from airborne emissions. The collective dose for the population of 500,000 to 880,000 people living within 50 miles (80 km) of the site would range from 0.017 to 0.4 person-rem/yr. This corresponds to about 9×10^{-6} to 2×10^{-4} LCF per year within the exposed population.

F.3.1.1.4 Cylinder Treatment Facility

The empty UF_6 cylinders from the conversion facilities would be decontaminated at a cylinder treatment facility before reuse or final disposal. Average radiological exposure incurred by involved workers would be less than 200 mrem/yr, and maximum exposures incurred by noninvolved workers and the off-site public would be less than 3×10^{-5} mrem/yr. The estimated radiological impacts and cancer risks from cylinder treatment operations are presented in Tables F.4 and F.5, respectively.

Involved Workers. The average annual dose received by involved workers would be approximately 160 mrem/yr, which was calculated by evenly distributing the estimated collective dose of 16 person-rem/yr to a worker population of approximately 100. The average dose is a small fraction of the dose limit of 5,000 mrem/yr and corresponds to a cancer risk of 6×10^{-5} per year (1 chance in 16,000 of developing 1 LCF per year). The collective number of LCFs among the involved workers would be 6×10^{-3} per year.

Noninvolved Workers. Only a small amount of U_3O_8 (0.01 lb/yr) would be released to the atmosphere from the cylinder treatment facility. Radiological exposure to the noninvolved worker MEI would be negligible (less than 1.8×10^{-5} mrem/yr). The collective dose would range from 6.5×10^{-6} to 1.4×10^{-5} person-rem/yr for a population of 2,000 to 3,500.

General Public. The radiation exposure of the general public MEI from normal operations at the treatment facility would be negligible (less than 2.7×10^{-5} mrem/yr). The collective dose to the off-site population of 500,000 to 880,000 people would be less than 4.1×10^{-4} person-rem/yr.

F.3.1.2 Chemical Impacts

Potential chemical impacts to human health from normal operations at the conversion facilities would result primarily from exposure to trace amounts of insoluble uranium compounds (i.e., UO_2, U_3O_8, and UF_4) and HF released from process exhaust stacks. Risks from normal operations were quantified on the basis of calculated hazard indices. Information on the exposure assumptions, health effects assumptions, reference doses used for uranium compounds and HF, and calculational methods used in the chemical impact analysis are provided in Appendix C and Cheng et al. (1997).

Conversion to U_3O_8, UO_2, or metal would result in very low-level exposures to hazardous chemicals. No adverse health effects would be expected during normal operations. Hazardous chemical human health impacts resulting from normal operations of the conversion facilities are summarized in Table F.6. The hazard indices for all conversion processes are more than 5,000 times lower than the hazard index of 1, which is the level at which adverse health effects might be expected to occur in some exposed individuals. The range of chemical exposures to the noninvolved workers and general public results primarily from the assumed locations of the representative conversion facilities.

One of the UO_2 conversion options, the gelation process, would also generate emissions of the chemical trichloroethylene from the process stack. The estimated increased lifetime carcinogenic risk of cancer incidence for noninvolved workers and members of the general public from exposure to trichloroethylene would be less than 1×10^{-8}, a very small increased risk that would not be considered an adverse impact.

TABLE F.6 Chemical Impacts to Human Health for Conversion/Treatment Options under Normal Operations[a]

	Impacts to Receptor			
	Noninvolved Workers[b]		General Public	
Option	Hazard Index for MEI[c,d]	Population Risk[e] (persons at risk/yr)	Hazard Index for MEI[c,f]	Population Risk[e] (persons at risk/yr)
Conversion to U_3O_8	3.9×10^{-7} – 1.5×10^{-6}	–	3.4×10^{-5} – 1.2×10^{-4}	–
Conversion to UO_2	7.5×10^{-7} – 3.1×10^{-6}	–	6.2×10^{-5} – 1.9×10^{-4}	–
Conversion to metal	4.8×10^{-7} – 3.0×10^{-6}	–	4.1×10^{-5} – 1.5×10^{-4}	–
Cylinder treatment	4.2×10^{-10} – 1.5×10^{-9}	–	3.5×10^{-8} – 7.1×10^{-8}	–

[a] Impacts are reported as ranges, which result from variations in the three representative facility locations and the different conversion technologies within each option.

[b] Noninvolved workers include individuals who work at the facility but are not directly involved in handling hazardous materials and individuals who work on-site but not within the facility.

[c] The hazard index is an indicator for potential adverse health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation. Hazard indices were calculated for combined exposures to uranium compounds and HF.

[d] The MEI for the noninvolved workers was assumed to be located on-site 100 m or more from the release point at the location that would result in the largest exposure from airborne emissions, including inhalation and incidental ingestion of contaminated soil.

[e] Calculation of population risk is not applicable when the corresponding hazard index for the MEI is less than 1.

[f] The MEI for the general public was assumed to be located off-site at the location that would result in the largest exposures through inhalation and ingestion of soil and drinking water.

The empty UF_6 cylinders from the conversion facilities would be decontaminated at a cylinder treatment facility prior to final disposal. Estimates of the hazardous chemical impacts to human health resulting from cylinder treatment operations are also summarized in Table F.6. The hazard indices from the cylinder treatment facility would be hundreds of times lower than those predicted for the conversion options, for which no adverse human health impacts were predicted.

F.3.2 Human Health — Accident Conditions

A range of accidents covering the spectrum from high-frequency/low-consequence accidents to low-frequency/high-consequence accidents has been presented in the engineering analysis report (LLNL 1997). These accidents are listed in Table F.7. The following sections present the results for radiological and chemical health impacts of the highest-consequence accident in each frequency category. Results for all accidents listed in Table F.7 are presented in Policastro et al. (1997). A detailed description of the methodology and assumptions used in the calculations is also provided in Appendix C and Policastro et al. (1997).

F.3.2.1 Radiological Impacts

Table F.8 lists the radiological doses to various receptors for the accidents that give the highest dose from each frequency category. The LCF risks for these accidents are given in Table F.9. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions, three representative sites, and two or three technologies were considered for each conversion option (see Appendix C). The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely category have a probability of occurrence of between 1 in 10,000 and 1 in 1 million per year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

- The maximum radiological dose to noninvolved worker and general public MEIs (assuming that an accident occurred) would be 9.2 rem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the U.S. Nuclear Regulatory Commission (NRC 1994).

- The overall radiological risk to noninvolved worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table F.9] by the annual probability of occurrence by the number of years of operations) would be less than 1 for all of the conversion facility accidents.

F.3.2.2 Chemical Impacts

The accidents considered in this section are listed in Table F.7. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables F.10 and F.11. The results are presented as (1) number of people with potential for adverse effects and (2) number of

TABLE F.7 Accidents Considered for the Conversion Options

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to U_3O_8					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Cylinder valve shear	A single UF_6 cylinder is mishandled, etc., resulting in the shearing of the cylinder valve and loss of solid UF_6 from the valve onto the ground.	UF_6	0.25	120 (continuous)	Ground
HF system leak during upgrading of HF to anhydrous HF	An HF absorber column line leaks 5% of its flowing contents due to potential vessel, pump, or pipe leakage.	HF	216	15	Stack
HF system leak during HF neutralization	An HF distillation column line leaks 5% of its flowing contents due to potential vessel, pump, or pipe leakage.	HF	10	15	Stack
Loss of cooling water during upgrading of HF to anhydrous HF	Cooling water is lost to the HF distillation column condenser, and HF vapor is removed by a limestone bed before reaching the environment.	HF	22	2	Stack
Loss of cooling water during HF neutralization	Cooling water is lost to the absorption column coolers, and HF vapor is released to the atmosphere.	HF	19	2	Stack
Loss of off-site electrical power	Off-site electrical power is lost, which halts facility operations but does not result in significant releases to the environment.	No release	NA[b]	NA	NA
U_3O_8 drum spill	A single U_3O_8 drum is damaged by a forklift and spills its contents onto the floor inside the storage facility.	U_3O_8	0.00014	30	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Ammonia release	An ammonia fill line is momentarily disconnected, and ammonia is released at grade.	Ammonia	255	1	Ground
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
HF pipeline rupture	An earthquake ruptures an underground pipeline transporting HFs, releasing it to the ground.	HF	500	10	Soil
HF storage tank overflow	An HF storage tank overflows during filling, spilling onto the floor; the pool of HF evaporates and is released through the building stack.	HF	45	15	Stack

TABLE F.7 (Cont.)

Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to U_3O_8 (Cont.)					
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in.-deep water pool.	HF	150	60 (continuous)	Ground
Earthquake	The U_3O_8 storage building is damaged during a design-basis earthquake, and 10% of the stored drums are breached.	U_3O_8	41	30	Ground
Hydrogen explosion	Due to equipment malfunction, hydrogen that accumulated in the conversion reactor ignites and causes the reactor to rupture.	U_3O_8 HF	0.27 7	30	Stack
Tornado	A windblown missile from a design-basis tornado pierces a single U_3O_8 drum in the U_3O_8 storage building.	U_3O_8	69	0.5	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Anhydrous HF tank rupture	Large seismic or beyond-design-basis event causes rupture of a filled anhydrous HF storage tank.	HF	7,920	120	Ground
Ammonia tank rupture	Large seismic or beyond-design-basis event causes rupture of a filled ammonia storage tank.	Ammonia	118,000	20	Ground
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground

TABLE F.7 (Cont.)

Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to UO_2					
Likely Accidents (frequency: 1 or more times in 100 years)					
Ammonia stripper overpressure	Cooling water is lost to the ammonia stripping column, and ammonia vapor is released to the atmosphere.	Ammonia	15	1	Ground
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Cylinder valve shear	A single UF_6 cylinder is mishandled, etc., resulting in shearing of the cylinder valve and loss of solid UF_6 from the valve onto the ground.	UF_6	0.25	120 (continuous)	Ground
HF system leak during upgrading of HF to anhydrous HF	An HF absorber line leaks 5% of its flowing contents due to potential vessel, pump, or pipe leakage.	HF	216	15	Stack
HF system leak during HF neutralization	An HF distillation column line leaks 5% of its flowing contents due to potential vessel, pump, or pipe leakage.	HF	10	15	Stack
Loss of cooling water during upgrading of HF to anhydrous HF	Cooling water is lost to the HF distillation column condenser, and HF vapor is removed by a limestone bed before reaching the environment.	HF	22	2	Stack
Loss of cooling water during HF neutralization	Cooling water is lost to the absorption column coolers, and HF vapor is released to the atmosphere.	HF	19	2	Stack
Loss of off-site electrical power	Off-site electrical power is lost, which halts facility operations but does not result in significant releases to the environment.	No release	NA	NA	NA
Trichloroethylene (TCE) spill	A TCE storage tank spills onto the floor during operations, and the pool of TCE evaporates and is released to the environment.	TCE	120	120	Stack
Trichloroethylene vapor leak	The exhaust line from the gel sphere dryers leaks 5% of its flowing contents due to potential pipe leakage.	TCE	20	60	Stack
UO_2 drum spill	A single UO_2 drum is damaged by a forklift and spills its contents onto the floor inside the storage facility.	UO_2	0.000056	30	Stack

TABLE F.7 (Cont.)

Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to UO_2 (Cont.)					
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Ammonia release	An ammonia fill line is momentarily disconnected, and ammonia is released at grade.	Ammonia	255	1	Ground
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
HF pipeline rupture	An earthquake ruptures an underground pipeline transporting HF, releasing it to the ground.	HF	500	10	Soil
HF storage tank overflow	An HF storage tank overflows during filling, spilling onto the floor; the pool of HF evaporates and is released to the indoor air of the process building.	HF	45	15	Stack
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in.-deep water pool.	HF	147	60 (continuous)	Ground
Earthquake	The UO_2 storage building is damaged during a design-basis earthquake, and 10% of the stored drums are breached.	UO_2	9.8	30	Ground
Hydrogen explosion	Due to equipment malfunction, hydrogen that accumulated in the ceramic UO_2 conversion reactor ignites and causes the reactor to rupture.	UO_2 HF	0.25 7	30	Stack
Hydrogen explosion	Due to equipment malfunction, hydrogen that accumulated in the gelation conversion reactor ignites and causes the reactor to rupture.	UO_2	0.017	30	Stack
Tornado	A windblown missile from a design-basis tornado pierces a single ceramic UO_2 drum in the UO_2 storage building.	UO_2	3.7	0.5	Ground
Tornado	A windblown missile from a design-basis tornado pierces a single UO_2 drum produced by gelation in the UO_2 storage building.	UO_2	5.6	0.5	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground

TABLE F.7 (Cont.)

Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to UO_2 (Cont.)					
Incredible Accidents (frequency: less than 1 in 1 million years)					
Anhydrous HF tank rupture	Large seismic or beyond-design-basis event causes rupture of a filled anhydrous HF storage tank.	HF	7,920	120	Ground
Ammonia tank rupture	Large seismic or beyond-design-basis event causes rupture of a filled ammonia storage tank.	Ammonia	117,920	20	Ground
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Conversion to Metal					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Cylinder valve shear	A single UF_6 cylinder is mishandled, etc., resulting in shearing of the cylinder valve and loss of solid UF_6 from the valve onto the ground.	UF_6	0.25	120 (continuous)	Ground
HF system leak	An off-gas line from the conversion reactor to the condenser leaks 5% of its flowing contents due to potential vessel, pump, or pipe leakage.	HF	3.6	15	Stack
Loss of cooling water	Cooling water is lost to the reactor HF coolers, and HF vapor is released to the atmosphere.	HF	17	2	Stack
Loss of off-site electrical power	Off-site electrical power is lost, which halts facility operations but does not result in significant releases to the environment.	No release	NA	NA	NA
UF_4 drum spill	A single UF_4 drum is damaged by a forklift and spills its contents onto the floor of the process building.	UF_4	0.00015	30	Stack

TABLE F.7 (Cont.)

Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to Metal (Cont.)					
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Ammonia release	An ammonia fill line is momentarily disconnected, and ammonia is released at grade.	Ammonia	255	1	Ground
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
HF pipeline rupture	An earthquake ruptures an underground pipeline transporting HF and releasing it to the ground.	HF	500	10	Soil
HF storage tank overflow	An HF storage tank overflows during filling, spilling onto the floor; the pool of HF evaporates and is released to the indoor air of the process building.	HF	45	15	Stack
Nitric acid (HNO_3) release	Due to equipment failure, hot HNO_3 flows through a relief valve.	HNO_3	6	2	Stack
Uranium metal fire	The wooden boxes containing the uranium metal product burn, affecting a total of 34 uranium derbies.	U_3O_8	0.058	30	Stack
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in.-deep water pool.	HF	147	60 (continuous)	Ground
Earthquake	The uranium product storage building is damaged during a design-basis earthquake, and some of the boxes containing uranium metal are breached.	U_3O_8	0.058	30	Ground
Hydrogen explosion	Due to equipment malfunction, hydrogen that accumulated in the conversion reactor ignites and causes the reactor to rupture.	UF_4 HF	0.05 2	30	Stack
Reactor rupture	A reactor containing molten uranium metal is damaged or breached, releasing hot molten uranium metal as airborne particles.	U_3O_8	0.0026	15	Stack
Tornado	A design-basis tornado does not result in significant releases because uranium is in metal form.	No release	NA	NA	NA
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground

TABLE F.7 (Cont.)

Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Conversion to Metal (Cont.)					
Incredible Accidents (frequency: less than 1 in 1 million years)					
Anhydrous HF tank rupture	Large seismic or beyond-design-basis event causes rupture of a filled anhydrous HF storage tank.	HF	7,920	120	Ground
Ammonia tank rupture	Large seismic or beyond-design-basis event causes rupture of a filled ammonia storage tank.	Ammonia	118,000	20	Ground
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Cylinder Treatment Facility					
Likely Accidents (frequency: 1 or more times in 100 years)					
Loss of off-site electrical power	Off-site electrical power is lost, which halts facility operations but does not result in significant releases to the environment.	No release	NA	NA	NA
U_3O_8 drum spill	A single U_3O_8 drum is damaged by a forklift and spills its contents onto the ground outside the storage facility.	U_3O_8	0.138	30	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Loss of scrubber water	Water is lost to both HF scrubbers, and HF is released with the off gas.	HF	26	30	Stack
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Depleted UF_6 cylinder rupture	A truck crashes into the depleted UF_6 heel storage pad, damaging two cylinders; the fuel from the truck ignites and releases all of the depleted UF_6.	UO_2F_2 HF	38.5 10	30	Ground
Earthquake	The solids product building is damaged during a design-basis earthquake, and 50% of the stored drums are breached.	U_3O_8	1.9	30	Ground
HF aqueous tank rupture	The evaporator tank fails, releasing its entire contents of HF to the floor; the pool of aqueous HF evaporates and is released to the indoor air of the process building.	HF	3.4	60	Stack
Tornado	A windblown missile from a design-basis tornado pierces a single U_3O_8 drum in the solids product building.	U_3O_8	69	0.5	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA

[a] Ground-level releases were assumed to occur outdoors on concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

[b] NA = not applicable.

TABLE F.8 Estimated Radiological Doses per Accident Occurrence for the Conversion Options

Option/Accident[a]	Frequency Category[b]	Maximum Dose[c]				Minimum Dose[c]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Conversion to U_3O_8									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	7.1	2.3×10^{-3}	3.0×10^{-1}	3.3×10^{-3}	8.1×10^{-2}	7.8×10^{-5}	7.4×10^{-3}
Earthquake	EU	9.2	8.4×10^{2}	2.7×10^{-1}	2.0×10^{1}	3.9×10^{-1}	9.6	9.2×10^{-3}	8.0×10^{-1}
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	2.5	4.9×10^{-3}	2.7×10^{-1}	8.7×10^{-4}	2.2×10^{-1}	6.2×10^{-4}	2.5×10^{-2}
Conversion to UO_2									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	7.1	2.3×10^{-3}	3.0×10^{-1}	3.3×10^{-3}	8.1×10^{-2}	7.8×10^{-5}	7.4×10^{-3}
Earthquake	EU	2.3	2.1×10^{2}	6.8×10^{-2}	5.1	9.6×10^{-2}	2.4	2.3×10^{-3}	2.0×10^{-1}
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	2.5	4.9×10^{-3}	2.7×10^{-1}	8.7×10^{-4}	2.2×10^{-1}	6.2×10^{-4}	2.5×10^{-2}
Conversion to metal									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	7.1	2.3×10^{-3}	3.0×10^{-1}	3.3×10^{-3}	8.1×10^{-2}	7.8×10^{-5}	7.4×10^{-3}
Uranium metal fire	U	2.4×10^{-6}	1.2×10^{-3}	2.6×10^{-6}	2.0×10^{-2}	4.9×10^{-7}	2.4×10^{-11}	2.0×10^{-6}	1.1×10^{-3}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	7.5	1.5×10^{-2}	5.6×10^{1}	3.7×10^{-3}	5.2×10^{-1}	1.9×10^{-3}	5.2×10^{-1}
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	2.5	4.9×10^{-3}	2.7×10^{-1}	8.7×10^{-4}	2.2×10^{-1}	6.2×10^{-4}	2.5×10^{-2}
Cylinder treatment									
U_3O_8 drum spill	L	3.1×10^{-2}	2.8	9.2×10^{-4}	6.9×10^{-2}	1.3×10^{-3}	3.2×10^{-2}	3.1×10^{-5}	2.7×10^{-3}
Tornado[d]	EU	4.3×10^{-1}	3.8×10^{1}	1.3×10^{-2}	2.5	4.3×10^{-1}	1.1×10^{1}	1.0×10^{-2}	4.5×10^{-1}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[c] Maximum and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

[d] Meteorological conditions analyzed for the tornado were D stability with 20 m/s wind speed.

TABLE F.9 Estimated Radiological Health Risks per Accident Occurrence for the Conversion Options[a]

		Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI	Population	MEI	Population	MEI	Population	MEI	Population
Conversion to U_3O_8									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	3×10^{-3}	1×10^{-6}	2×10^{-4}	1×10^{-6}	3×10^{-5}	4×10^{-8}	4×10^{-6}
Earthquake	EU	4×10^{-3}	3×10^{-1}	1×10^{-4}	1×10^{-2}	2×10^{-4}	4×10^{-3}	5×10^{-6}	4×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	1×10^{-3}	2×10^{-6}	1×10^{-4}	3×10^{-7}	9×10^{-5}	3×10^{-7}	1×10^{-5}
Conversion to UO_2									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	3×10^{-3}	1×10^{-6}	2×10^{-4}	1×10^{-6}	3×10^{-5}	4×10^{-8}	4×10^{-6}
Earthquake	EU	9×10^{-4}	8×10^{-2}	3×10^{-5}	3×10^{-3}	4×10^{-5}	1×10^{-3}	1×10^{-6}	1×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	1×10^{-3}	2×10^{-6}	1×10^{-4}	3×10^{-7}	9×10^{-5}	3×10^{-7}	1×10^{-5}
Conversion to metal									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	3×10^{-3}	1×10^{-6}	2×10^{-4}	1×10^{-6}	3×10^{-5}	4×10^{-8}	4×10^{-6}
Uranium metal fire	U	1×10^{-9}	5×10^{-7}	1×10^{-9}	1×10^{-5}	2×10^{-10}	1×10^{-14}	1×10^{-9}	6×10^{-7}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	3×10^{-3}	7×10^{-6}	3×10^{-2}	1×10^{-6}	2×10^{-4}	1×10^{-6}	3×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	1×10^{-3}	2×10^{-6}	1×10^{-4}	3×10^{-7}	9×10^{-5}	3×10^{-7}	1×10^{-5}
Cylinder treatment									
U_3O_8 drum spill	L	1×10^{-5}	1×10^{-3}	5×10^{-7}	3×10^{-5}	5×10^{-7}	1×10^{-5}	2×10^{-8}	1×10^{-6}
Tornado[e]	EU	2×10^{-4}	2×10^{-2}	7×10^{-6}	1×10^{-3}	2×10^{-4}	4×10^{-3}	5×10^{-6}	2×10^{-4}

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCFs) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one that would result in the highest risks to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum risks reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] Meteorological conditions analyzed for the tornado were D stability with 20 m/s wind speed.

TABLE F.10 Number of Persons with Potential for Adverse Effects from Accidents under the Conversion Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Conversion to U_3O_8									
Corroded cylinder spill, dry conditions	L	Yes	240	No	0	Yes	2	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	520	Yes	10	Yes	52	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	310	Yes	2,500	Yes[f]	0	Yes	3
HF tank rupture	I	Yes	1,100	Yes	41,000	Yes	770	Yes	18
Conversion to UO_2									
Corroded cylinder spill, dry conditions	L	Yes	240	No	0	Yes	2	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	520	Yes	10	Yes	52	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	310	Yes	2,500	Yes[f]	0	Yes	3
HF tank rupture	I	Yes	1,100	Yes	41,000	Yes	770	Yes	18
Conversion to metal									
Corroded cylinder spill, dry conditions	L	Yes	240	No	0	Yes	2	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	520	Yes	10	Yes	52	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	310	Yes	2,500	Yes[f]	0	Yes	3
HF tank rupture	I	Yes	1,100	Yes	41,000	Yes	770	Yes	18
Cylinder treatment									
U_3O_8 drum spill[g]	L	No	0	No	0	No	0	No	0
Loss of scrubber water[g]	U	No	0	No	0	No	0	No	0
Tornado[h]	EU	Yes	1	No	0	NA[i]	NA	NA	NA

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site population) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum values reflect differences in assumed meteorological conditions at the time of the accident. In general, the maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas the minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential adverse effects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the worker and general public population distributions for the representative sites were used, which did not show receptors at the MEI locations.

[g] These accidents would result in the largest plume sizes, although no people would be affected.

[h] Meteorological conditions analyzed for the tornado were D stability with 20 m/s wind speed.

[i] NA = not applicable.

TABLE F.11 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under the Conversion Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Conversion to U_3O_8									
Corroded cylinder spill, dry conditions	L	Yes	5	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	370	Yes[f]	0	Yes	3	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	440	Yes[f]	0	Yes	4	No	0
Ammonia tank rupture	I	Yes	420	Yes	1,700	Yes	180	Yes	8
Conversion to UO_2									
Ammonia stripper overpressure	L	Yes	40	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	370	Yes[f]	0	Yes	3	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	440	Yes[f]	0	Yes	4	No	0
Ammonia tank rupture	I	Yes	420	Yes	1,700	Yes	180	Yes	8
Conversion to metal									
Corroded cylinder spill, dry conditions	L	Yes	5	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	370	Yes[f]	0	Yes	3	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	440	Yes[f]	0	Yes	4	No	0
Ammonia tank rupture	I	Yes	420	Yes	1,700	Yes	180	Yes	8
Cylinder treatment									
U_3O_8 drum spill[g]	L	No	0	No	0	No	0	No	0
Loss of scrubber water[g]	U	No	0	No	0	No	0	No	0
Tornado[h]	EU	Yes[f]	0	No	0	NA[i]	NA	NA	NA

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site population) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accident. In general, the maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas the minimum risks would occur under D stability with 4 m/s wind speed. An exception is worker impacts for the ammonia tank rupture, for which maximum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential irreversible adverse affects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the worker and general public population distributions for the representative sites were used, which did not show receptors at the MEI locations.

[g] These accidents would result in the largest plume sizes, although no people would be affected.

[h] Meteorological conditions analyzed for the tornado were D stability with 20 m/s wind speed.

[i] NA = not applicable.

people with potential for irreversible adverse effects. The tables present the results for the accident within each frequency category that would affect the largest number of people (total of workers and off-site population) (Policastro et al. 1997). The numbers of noninvolved workers and members of the off-site public represent the impacts if the associated accident was assumed to occur. The accidents listed in Tables F.10 and F.11 are not identical because an accident with the largest impacts for adverse effects might not lead to the largest impacts for irreversible adverse effects. The impacts may be summarized as follows:

- If the accidents identified in Tables F.10 and F.11 did occur, the number of persons in the off-site population with potential for adverse effects would range from 0 to 41,000 (maximum corresponding to HF tank rupture), and the number of off-site persons with potential for irreversible adverse effects would range from 0 to 1,700 (maximum corresponding to ammonia tank rupture).

- If the accidents identified in Tables F.10 and F.11 were to occur, the number of noninvolved workers with potential for adverse effects would range from 0 to 1,100 (maximum corresponding to HF tank rupture), and the number of noninvolved workers with potential for irreversible adverse effects would range from 0 to 440 (maximum corresponding to corroded cylinder spill, wet conditions — water pool).

- The largest impacts would be caused by HF tank rupture; corroded cylinder spill, wet conditions – rain; ammonia tank rupture; and vehicle-induced fire involving three full 48G cylinders. Accidents involving stack emissions would have very small impacts compared with accidents involving releases at ground level due to the large dilution (and lower source terms due to filtration and deposition) involved with the stack emissions.

- The bounding accidents for the conversion options (conversion to U_3O_8, UO_2, and metal) would have nearly identical impacts.

- For the most severe accidents in each frequency category, the noninvolved worker MEI and the public MEI would have the potential for both adverse effects and irreversible adverse effects. The likely accidents for each conversion option (frequency of more than one chance in 100 per year) would result in no potential adverse or irreversible adverse effects for the general public. The generally reduced impacts to the public MEI compared with the noninvolved worker MEI are related to dispersion of the chemical release with downwind distance (except for UF_6 cylinder fire with plume rise).

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (20 years, 2009 through 2028). The results indicate that the maximum risk values would be less than 1 for all accidents except the following:

- *Potential Adverse Effects:*

  Corroded cylinder spill, dry conditions (L, likely): Workers
  Corroded cylinder spill, wet conditions – rain (U, unlikely): Workers

- *Potential Irreversible Adverse Effects:*

  Corroded cylinder spill, dry conditions (L, likely): Workers
  Ammonia stripper overpressure (L, likely): Workers
  Corroded cylinder spill, wet conditions – rain (U, unlikely): Workers

These risk values are conservative because the numbers of people affected were based on assuming (1) meteorological conditions that would result in the maximum reasonably foreseeable plume size (i.e., F stability and 1 m/s wind speed) and (2) wind in the direction that would lead to maximum numbers of individuals exposed for noninvolved workers or for the general population.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated irreversible adverse effects was calculated. For the worker and general public accidents involving UF_6 releases shown in Table F.10, exposure to HF and uranium compounds could be high enough to result in death for 1% or less of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Thus, for the corroded cylinder spill accidents having a range of 0 to 440 irreversible adverse effects for noninvolved workers, approximately 0 to 4 worker deaths would be expected; no deaths would be expected for members of the general public from such accidents. For the ammonia tank rupture accident caused by an earthquake, exposure to ammonia would result in death for about 2% of the persons experiencing irreversible adverse effects. This would correspond to about 4 to 8 deaths among noninvolved workers and 0 to 34 deaths for the general public. These are the maximum potential consequences of the accidents; the upper ends of the ranges result from assuming worst-case weather conditions, with the wind blowing in the direction where the highest number of people would be exposed.

F.3.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries to all conversion facility workers was calculated using industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council (1995). Annual fatality and injury rates for construction and manufacturing, respectively, were used for the construction and operational phases of the conversion facility lifetime.

No on-the-job fatalities are predicted for any of the options analyzed, but a range of about 300 to 500 injuries is predicted during the conversion facility lifetimes. Overall, the largest impacts are predicted for conversion to UO_2 through gelation and for conversion to metal through batch reduction because these options require larger numbers of employees. All other conversion options would result in similar impacts; fewer impacts are predicted for the cylinder treatment facility (i.e., approximately 170 injuries).

Because the conversion technologies analyzed for conversion of U_3O_8 would employ almost the same number of workers, there are essentially no differences between them. There would be a probability of about 0.35 of an on-the-job fatality (sum of 0.18 for the construction phase and 0.17 for the operations phase) for the U_3O_8 conversion options (Table F.12). The predicted injury incidence would be about 285 injuries over the lifetime of the facility.

The predicted probability of worker fatalities for conversion to UO_2 ranges from 0.4 to 0.59 (Table F.12). The predicted injury incidence ranges from about 320 to 492 injuries over the lifetime of the UO_2 conversion facility. The upper ends of the ranges result from the larger number of workers required for operation of the gelation facility.

The predicted probability of worker fatalities for conversion to metal ranges from about 0.4 to 0.55 (Table F.12). The predicted injury incidence ranges from about 300 to 490 injuries over the lifetime of the metal conversion facility. The upper ends of the ranges result from the larger number of workers required for operation of the batch reduction facility.

For the cylinder treatment facility option, the probability of an on-the-job fatality is about 0.19 (sum of 0.08 for the construction phase and 0.11 for the operations phase) (Table F.12). The estimated injury incidence would be about 170 over the lifetime of the facility.

F.3.3 Air Quality

Additional details regarding the analysis of air quality impacts for the conversion option are presented in Tschanz (1997).

F.3.3.1 Construction

The annual emissions of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrocarbons (HC), carbon monoxide (CO), and particulate matter (PM_{10}) expected during conversion plant construction are listed in Table F.13. The estimated 1-hour maximum pollutant concentrations at the facility boundary during construction are shown in Table F.14. Additional estimates were made for the conversion technology that had the highest estimated 1-hour maximum pollutant concentrations (i.e., gelation); these estimated concentrations are given in Table F.15). Although all of these pollutant concentrations would be much higher than those for plant operations, they remain below

TABLE F.12 Potential Impacts to Human Health from Physical Hazards under Accident Conditions for the Conversion Options[a]

	Impacts to Conversion Facility Workers[b]			
	Incidence of Fatalities		Incidence of Injuries	
Option	Construction	Operations	Construction	Operations
Conversion to U_3O_8	0.18	0.16–0.17	66	215–219
Conversion to UO_2	0.22–0.30	0.18–0.29	79–108	243–384
Conversion to metal	0.22–0.25	0.17–0.30	79–92	222–395
Cylinder treatment	0.08	0.11	30	140

[a] Impacts are reported as ranges, which result from variations in the employment requirements for the different conversion technologies for each option.

[b] Potential hazards were estimated for all conversion facility workers.

Source: Injury and fatality rates used in calculations taken from National Safety Council (1995).

TABLE F.13 Emissions to the Atmosphere from Construction of a Depleted UF_6 Conversion Plant during the Peak Year

	Emissions to Atmosphere (tons/yr)				
Option	SO_2	NO_2	HC	CO	PM_{10}
Conversion to U_3O_8	2	28	8	190	40–50
Conversion to UO_2	2–3	30–46	8–13	200–320	50–60
Conversion to metal	2–3	30–40	8–12	200–270	50–60

Source: LLNL (1997).

ambient air quality standards. One possible exception is PM_{10}, for which concentrations were estimated to be 90% of the 24-hour standard of 150 $\mu g/m^3$. Some fugitive dust control measures would be necessary to mitigate this potentially high concentration. Construction of the conversion plant in a region of already high, even if compliant, ambient pollutant concentrations might require consideration of changes and/or controls for the emission of the other pollutants as well.

Estimated emissions from the cylinder treatment facility for all aspects of construction and operations are of the same order of magnitude (generally about 0.4 to 0.7 times as large) as those associated with the baseline cylinder transfer facility (see Appendix E), and the cylinder treatment facility area would be about half as large as the baseline cylinder transfer facility area. Except for the

TABLE F.14 Maximum 1-Hour Average Pollutant Concentrations at the Nearest Point on the Facility Boundary from Construction of a Conversion Facility[a]

	Pollutant ($\mu g/m^3$)				
Option	SO_2	NO_2	HC	CO	PM_{10}
Conversion to U_3O_8	26	360	100	2,400	520
Conversion to UO_2	25–37	380–570	100–160	2,400–3,900	620–740
Conversion to metal	25–36	360–480	100–140	2,500–3,200	610–720

[a] The ranges shown for some pollutants include results from the various technologies used for the conversion option and the differences in representative sites used for analysis.

TABLE F.15 Maximum Air Quality Impacts from Conversion Facility Construction[a]

	Estimated Pollutant Emissions[b]							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration[c] ($\mu g/m^3$)	Fraction of Standard[d]	Concentration[c] ($\mu g/m^3$)	Fraction of Standard[d]	Concentration[c] ($\mu g/m^3$)	Fraction of Standard[d]	Concentration[c] ($\mu g/m^3$)	Fraction of Standard[d]
CO	3,810	0.1	3,100	0.30	–	–	–	–
NO_x	–	–	–	–	–	–	16	0.17
SO_2	–	–	–	–	5.8	0.02	0.9	0.01
PM_{10}	–	–	–	–	136	0.90	21	0.42

[a] Estimated pollutant emissions are given for the conversion to UO_2 gelation option, which would have the highest emissions.

[b] Values are listed only for pollutant/averaging time period combinations that have applicable air quality standards.

[c] Concentrations are the second highest values estimated for one entire year. Short-term standards are not to be exceeded more than once per year.

[d] Ratio of the concentration to the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

1-hour average results, the analytical results shown in Table F.16 for the cylinder treatment facility are about 0.2 to 0.4 times as large as those shown in Appendix E, Tables E.9-E.11, for the cylinder transfer facility. The 1-hour average impacts of construction of a cylinder treatment facility would be essentially the same as those for cylinder transfer facility construction.

F.3.3.2 Operations

Hourly emission rates during operations were determined from annual emission rates given in the engineering analysis report (LLNL 1997); these rates are shown in Table F.17. The methods used to analyze the impacts of pollutant emissions are described in Appendix C. All air pollutant concentrations during operations would be well below applicable ambient air quality standards for all conversion options. The maximum ground-level atmospheric concentrations at the representative facility boundaries from the boiler stack's emissions are listed in Tables F.18 through F.20. At the upper ends of the ranges, the nearest any of the criteria pollutant concentrations would come to a corresponding air quality standard is the annual nitrogen oxides (NO_x) concentration, which would be between 0.0007 and 0.002 of the annual NO_x standard.

Maximum air quality impacts from the process stacks are also listed in Tables F.18 through F.20. State HF standards in Tennessee and Kentucky have been used for comparative purposes. The estimated 24-hour maximum HF concentrations at representative facility boundaries for the conversion to U_3O_8 with anhydrous HF are about 2% of the respective state standards. The batch conversion to uranium metal is the only case for which NO_2 would be emitted from the process stack, and the NO_2 emission rate from the process stack in that case would be about eight times larger than from the boiler stack. Nevertheless, the estimated maximum annual NO_2 concentrations at the representative facility boundaries are less than 1% of the respective state standards.

TABLE F.16 Air Quality Impacts from Construction of the Cylinder Treatment Facility

	Estimated Pollutant Emissions							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Range[a] ($\mu g/m^3$)	Fraction of Standard[b]	Range[a] ($\mu g/m^3$)	Fraction of Standard[b]	Range[a] ($\mu g/m^3$)	Fraction of Standard[b]	Range[a] ($\mu g/m^3$)	Fraction of Standard[b]
CO	1,800 – 3,500	0.088	310 – 450	0.045	120 – 180	–	7.2 – 13	–
NO_x	280 – 520	–	47 – 69	–	19 – 27	–	1.1 – 2.0	0.02
PM_{10}	390 – 720	–	65 – 95	–	26 – 37	0.25	1.5 – 2.6	0.052

[a] Concentrations are the second highest values estimated for one entire year. Short-term standards are not to be exceeded more than once per year.

[b] Ratio of the upper end of the concentration range to the respective air quality standard. A ratio of less than 1 indicates that the standard is not exceeded. Pollutant/averaging time period combinations for which no air quality standard exists are noted with a dash (–).

TABLE F.17 Emissions to the Atmosphere from Operation of a Depleted UF_6 Conversion Plant

	Emissions to Atmosphere (lb/yr)						
Option/Source	SO_2	NO_2	HC	CO	PM_{10}	HF	Uranium Compounds
Conversion to U_3O_8							
Boiler stack	60–80	8,300–10,000	180–200	4,100–5,000	310–400	–	–
Process stack	–	–	–	–	–	300–900	3.3 U_3O_8
Generator stack	60	400	400	2,300	80	–	–
Conversion to UO_2							
Boiler stack	23–820	3,800–110,000	170–2,300	800–55,000	290–4,100	–	–
Process stack	–	–	–	–	–	300–900	2.5–12 UO_2
Generator stack	54–80	400–720	400–690	2,300–3,700	20–140	–	–
Conversion to metal							
Boiler stack	60–100	8,200–14,000	170–290	4,000–6,700	300–500	–	–
Process stack	–	117,000	–	–	–	300	1.2–9.6 U_3O_8; 3.8 UF_4
Generator stack	54–60	460–600	410–490	2,700–3,600	90–120	–	–

Source: LLNL (1997).

Each emergency generator would operate for 300 hours or less during 1 year. When it was operating, however, an emergency generator would produce higher concentrations of criteria pollutants at the facility boundaries than would the boiler. The estimated pollutant concentrations from the generator are listed in Tables F.18 through F.20. Compared with the air quality standards, the estimated concentrations are no more than 5% of allowed values.

The boiler stack parameters are identical for the cylinder treatment facility and the baseline cylinder transfer facility (see Appendix E). Given the similarities in the input data, the results of the air quality analyses for the two facilities should be expected to be comparable. Although not presented explicitly here, the same can be said of the impacts for operations. In summary, all of the criteria pollutant impacts of the cylinder treatment facility would not differ substantially from those of the cylinder transfer facility; all of the impacts not explicitly noted here are considered to be negligible. The only pollutant of concern emitted by the cylinder treatment facility process stack would be HF, and it, too, would be comparable for the two facilities. The cylinder treatment facility process stack would produce maximum annual average HF concentrations of 1.6×10^{-6} $\mu g/m^3$. This concentration is several orders of magnitude smaller than any applicable HF air quality standard.

No quantitative estimate was made of the impacts on the criterion pollutant ozone. Ozone formation is a regional issue that would be affected by emissions data for the entire area around a proposed conversion site. The pollutants most related to ozone formation that would result from the

TABLE F.18 Air Quality Impacts from Operations for Conversion to U_3O_8

Option/ Stack/ Pollutant	Estimated Pollutant Emissions[a]							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]
Conversion to U_3O_8 with Anhydrous HF								
Boiler stack								
CO	0.92 – 1.01	3×10^{-5}	0.37 – 0.63	6×10^{-5}	–	–	–	–
NO_x	–	–	–	–	–	–	0.054 – 0.090	0.0009
Generator stack								
CO	320 – 440	0.011	64 – 270	0.027	–	–	Not calculated	
NO_x	–	–	–	–	–	–	Not calculated	
Process stack								
HF	–	–	–	–	0.025 – 0.069	0.02	0.0040 – 0.0073	2×10^{-5}
U_3O_8	–	–	–	–	–	–	1.4×10^{-5} – 2.6×10^{-5}	NS[d]
Conversion to U_3O_8 with HF Neutralization								
Boiler stack								
CO	0.81 – 0.89	2×10^{-5}	0.31 – 0.57	6×10^{-5}	–	–	–	–
NO_x	–	–	–	–	–	–	0.046 – 0.077	0.0008
Generator stack								
CO	320 – 440	0.011	64 – 270	0.027	–	–	Not calculated	
NO_x	–	–	–	–	–	–	Not calculated	
Process stack								
HF	–	–	–	–	0.0091 – 0.022	0.006	0.0012 – 0.0023	6×10^{-6}
U_3O_8	–	–	–	–	–	–	0.000013 – 0.000026	NS

[a] Values are listed only for pollutant/averaging time period combinations with air quality standards.

[b] Concentrations are the second highest values estimated for one entire year. Short-term standards are not to be exceeded more than once per year.

[c] Ratio of the upper end of the concentration range to the respective air quality standard. A ratio of less than 1 indicates that the standard is not exceeded.

[d] NS = No annual average air quality standard is available for U_3O_8.

TABLE F.19 Air Quality Impacts from Operations for Conversion to UO_2

Option/ Stack/ Pollutant	Estimated Pollutant Emissions[a] 1-Hour Average Range[b] ($\mu g/m^3$)	1-Hour Average Fraction of Standard[c]	8-Hour Average Range[b] ($\mu g/m^3$)	8-Hour Average Fraction of Standard[c]	24-Hour Average Range[b] ($\mu g/m^3$)	24-Hour Average Fraction of Standard[c]	Annual Average Range[b] ($\mu g/m^3$)	Annual Average Fraction of Standard[c]
Conversion to UO_2 with Anhydrous HF								
Boiler stack								
CO	0.77 – 0.82	2×10^{-5}	0.31 – 0.51	5×10^{-5}	–	–	–	–
NO_x	–	–	–	–	–	–	0.045 – 0.079	0.0008
Generator stack								
CO	550 – 690	0.017	120 – 440	0.044	–	–	Not calculated	
NO_x	–	–	–	–	–	–	Not calculated	
Process stack								
HF	–	–	–	–	0.020 – 0.052	0.015	0.0030 – 0.0064	2×10^{-5}
U_3O_8	–	–	–	–	–	–	4×10^{-5} – 8.5×10^{-5}	NS[d]
Conversion to UO_2 with HF Neutralization								
Boiler stack								
CO	0.71 – 0.77	2×10^{-5}	0.28 – 0.47	5×10^{-5}	–	–	–	–
NO_x	–	–	–	–	–	–	0.041 – 0.070	0.0007
Generator stack								
CO	550 – 690	0.017	120 – 440	0.044	–	–	Not calculated	
NO_x	–	–	–	–	–	–	Not calculated	
Process stack								
HF	–	–	–	–	0.0067 – 0.017	0.005	0.00099 – 0.0021	5×10^{-6}
U_3O_8	–	–	–	–	–	–	4.0×10^{-5} – 8.4×10^{-5}	NS[d]
Conversion to UO_2 with Gelation Process								
Boiler stack								
CO	1.7 – 1.8	5×10^{-5}	0.71 – 1.3	1×10^{-4}	–	–	–	–
NO_x	–	–	–	–	–	–	0.058 – 0.17	0.002
Generator stack								
CO	NA[e]	NA	NA	NA	NA	NA	NA	NA
NO_x	NA	NA	NA	NA	NA	NA	NA	NA
Process stack								
HF	–	–	–	–	0.016 – 0.029	0.01	0.0022 – 0.0040	1×10^{-5}
U_3O_8	–	–	–	–	–	–	1.0×10^{-5} – 1.7×10^{-5}	NS[d]

[a] Values are listed only for pollutant/averaging time period combinations with air quality standards.

[b] Concentrations are the second highest values estimated for one entire year. Short-term standards are not to be exceeded more than once per year.

[c] Ratio of the upper end of the concentration range to the respective air quality standard. A ratio of less than 1 indicates that the standard is not exceeded.

[d] NS = No annual average air quality standard is available for U_3O_8.

[e] NA = Data not available.

TABLE F.20 Air Quality Impacts from Operations for Conversion to Uranium Metal

Option/ Stack/ Pollutant	Estimated Pollutant Emissions[a]							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]	Range[b] ($\mu g/m^3$)	Fraction of Standard[c]
Batch Process								
Boiler stack								
CO	0.88 – 0.90	2×10^{-5}	0.35 – 0.56	6×10^{-5}	–	–	–	–
NO_x	–	–	–	–	–	–	0.049 – 0.101	0.0010
Generator stack								
CO	580 – 720	0.018	120 – 460	0.046	–	–	Not calculated	
NO_x	–	–	–	–	–	–	Not calculated	
Process stack								
HF	–	–	–	–	0.0061 – 0.0125	0.004	0.00083 – 0.0019	5×10^{-6}
UF_4	–	–	–	–	–	–	1.0×10^{-5} – 2.4×10^{-5}	NS[d]
U_3O_8	–	–	–	–	–	–	2.6×10^{-5} – 6.1×10^{-5}	NS
NO_2	–	–	–	–	–	–	0.32 – 0.74	0.007
Continuous Process								
Boiler stack								
CO	0.71 – 0.77	2×10^{-5}	0.28 – 0.47	5×10^{-5}	–	–	–	–
NO_x	–	–	–	–	–	–	0.042 – 0.072	0.0007
Generator stack								
CO	550 – 690	0.017	120 – 440	0.044	–	–	Not calculated	
NO_x	–	–	–	–	–	–	Not calculated	
Process stack								
HF	–	–	–	–	0.0068 – 0.0172	0.005	0.0010 – 0.0021	5×10^{-6}
UF_4	–	–	–	–	–	–	1.3×10^{-5} – 2.7×10^{-5}	NS
U_3O_8	–	–	–	–	–	–	4.1×10^{-5} – 8.6×10^{-5}	NS

[a] Values are listed only for pollutant/averaging time period combinations with air quality standards.

[b] Concentrations are the second highest values estimated for one entire year. Short-term standards are not to be exceeded more than once per year.

[c] Ratio of the upper end of the concentration range to the respective air quality standard. A ratio of less than 1 indicates that the standard is not exceeded.

[d] NS = No annual average air quality standard is available for this pollutant.

conversion of depleted UF_6 are HC and NO_x. In later Phase II studies, when specific technologies and sites would be selected, the potential effects on ozone of these pollutants at a proposed site could be put in perspective by comparing them with the total emissions of HC and NO_x in the surrounding area. Small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region.

F.3.4 Water and Soil

This section discusses impacts of the conversion options on surface water, groundwater, and soils. The impacts are evaluated over a range of conditions present at the representative sites and are also relevant for a similarly sized generic site located in the vicinity of a river that could be used to supply water for construction and normal operations and to receive liquid waste discharges. The major conversion option parameters are summarized in Table F.21.

F.3.4.1 Surface Water

The methodology used to determine potential impacts to surface water for each conversion technology is described in Appendix C and Tomasko (1997).

F.3.4.1.1 Conversion to U_3O_8

Construction. Construction of a U_3O_8 conversion facility would produce increased runoff to nearby surface waters because of replacing soil and vegetation with either buildings or paved areas, approximately 13 acres (5.3 ha) (LLNL 1997). The amount of increased runoff would be negligible compared with the assumed existing area for runoff (0.3 to 0.8% of the representative site areas). None of the construction activities would measurably affect floodplains.

Table F.21 shows the quantity of water that would be used during construction of the U_3O_8 conversion facility (about 8 million gal/yr). This water would be withdrawn from nearby rivers or pumped from underlying aquifers. If the rate of water consumption were constant, the average rate of withdrawal would be about 15 gpm. This rate of withdrawal would be negligible compared to average flows in the adjacent rivers (less than 0.0001%). If the water were obtained from aquifers, there would be no impacts to the surface waters. Construction impacts would, therefore, range from none to negligible.

For construction, the net volume of water disposed of would be about 4 million gal/yr (7.6 gpm) (Table F.21). The primary contaminants of concern would be construction chemicals, organics, and some suspended solids. The wastewater would be discharged to nearby surface waters under a National Pollutant Discharge Elimination System (NPDES) permit, or to an appropriate

TABLE F.21 Summary of Conversion Option Parameters Affecting Water Quality and Soil[a]

Option	Disturbed Land Area (acres)	Operations Area (acres)	Construction Water (million gal/yr)	Operations Water (million gal/yr)
Conversion to U_3O_8	20	13	Raw = 8 Waste = 4	Raw = 34 – 47 Waste = 15 – 23 Sanitary = 1.2
Conversion to UO_2	22 – 31	14 – 20	Raw = 4 – 12 Waste = 5 – 6	Raw = 41 – 285 Waste = 9.7 – 135 Sanitary = 0.7 – 2.3
Conversion to metal	23 – 26	15 – 16	Raw = 10 – 12 Waste = 5 – 6	Raw = 55 Waste = 25 – 26 Sanitary = 1.4 – 2.3

Option	Accident Scenario	Radioactive Release to Surface Water[a] (Ci/yr)	Radioactive Effluent Concentration[b] (pCi/L)	Dilution Factor[c]	Surface Water Concentration (pCi/L)
Conversion to U_3O_8	HF pipeline break	0.001	12 – 17	47,000 – 4,200,000	4.1×10^{-6} – 2.6×10^{-4}
Conversion to UO_2	HF pipeline break	0.002 – 0.003	6 – 21	42,000 – 500,000	1.2×10^{-5} – 5.0×10^{-4}
Conversion to metal	HF pipeline break	0.001 – 0.002	10 – 21	42,000 – 2,600,000	4.0×10^{-6} – 4.9×10^{-4}

[a] Data from engineering analysis report (LLNL 1997).

[b] Concentration derived from estimated annual radioactive release and annual wastewater discharge.

[c] Dilution factor based on average flow conditions in receiving rivers.

wastewater sewer. By following good engineering practices (e.g., stockpiling materials away from surface water drainages, covering construction piles with tarps to prevent erosion by precipitation, and cleaning up small chemical spills as soon as they occur), concentrations in the wastewater would be small (well below any drinking water criteria).

Once in the surface water, mixing and dilution of the pollutants would occur. This dilution would be greater than 270,000:1 for average flow conditions in nearby rivers. This amount of dilution would reduce any contamination present to concentrations well below regulatory standards. Because the concentration of contamination in the water would be very low, impacts to sediment in the streams would also be negligible.

Operations. For normal operations, no impacts would occur to surface runoff, and there would be no measurable impacts on floodplains (effluent discharges to surface waters less than 0.001% of the average flows). As indicated in Table F.21, normal operation of the U_3O_8 conversion facility would require at most 47 million gal/yr (approximately 89 gpm) of raw water. If this water were obtained from nearby rivers, impacts would be negligible, less than 0.004% of the average flows. If the raw water were obtained from wells, there would be no impacts to surface waters.

A maximum of 23 million gal/yr of wastewater would be generated during operations, including cooling tower blowdown, process water, and industrial waste water. Another 1.2 million gal/yr of sanitary wastewater would be produced (Table F.21). For constant rates of discharge, about 44 gpm of wastewater and 2.3 gpm of sanitary water would be released to the environment at approved NPDES locations.

The primary contaminants of concern for the wastewater would be uranium and chemicals used to inhibit rust, reduce friction, and enhance heat exchange (e.g., copolymers, phosphates, phosphonates, calcium, magnesium, nitrates, sodium, and potassium). As discussed in the engineering analysis report (LLNL 1997), approximately 0.001 Ci/yr of uranium with an activity of 4×10^{-7} Ci/g would be released in the discharge water. For a waste volume of 23 million gal/yr (Table F.21), the uranium concentration in the effluent would be about 30 μg/L. After dilution in nearby surface water, the concentration would be much less than the proposed U.S. Environmental Protection Agency (EPA) drinking water standard for uranium of 20 μg/L, used here for comparison. Concentrations of the other chemicals released would also be expected to be very low and within the guidelines of an NPDES permit.

Accident Scenarios. Most of the accidents analyzed would involve outdoor releases on impermeable concrete pads in the cylinder yards; such releases could be cleaned up with little loss of the contaminated material to the soil. The only postulated accident that would release contaminated water to the environment is an HF pipeline break produced by an earthquake (Table F.21). Anhydrous HF would be pumped from the process building to the HF storage building through an underground pipeline that would carry liquid HF at a rate of 10 gpm (0.63 L/s) through 200 ft (61 m) of 1-in. (2.5-cm) pipe. For this accident scenario, 100% of the HF would drain into the ground at a point 3 ft (0.91 m) below grade during a 10-minute period. Approximately 500 lb (227 kg) of liquid HF (60 gal [227 L]) would be released. After 48 hours, the contaminated soil was assumed to be removed. Because of the rapid response to the accident, the HF would have little time to travel into the soil. For a silty sand, the travel distance would be about 2 ft (6.1 m) (Tomasko 1997). Removal of the contaminated soil and soil water would prevent any contamination problems to the groundwater and would prevent any cross contamination with surface waters. Therefore, there would be no net impact from this accident. Because this accident scenario would not affect surface runoff or existing floodplains, impacts to these parameters would also be nonexistent.

F.3.4.1.2 Conversion to UO_2

The environmental parameters associated with the UO_2 conversion alternatives are similar to those for U_3O_8 conversion (Table F.21), except for raw water use, which would be about five times larger for normal operations. If water were withdrawn from a nearby river, impacts would be negligible and would be less than 0.03% of the average flows. If it were withdrawn from wells, there would be no surface water impacts. Because of this option's similarities to the U_3O_8 conversion option, impacts to surface water produced by UO_2 conversion would be essentially the same as those for U_3O_8 conversion (i.e., none to negligible).

As was the case for the conversion to U_3O_8 option, discharge waters would receive from 0.002 to 0.003 Ci/yr. For the water discharges listed in Table F.21, the equivalent concentrations would range from 6 to 76 pCi/L (30 to 400 μg/L). After dilution in nearby surface waters, concentrations would be much less than the EPA proposed drinking water standard for uranium, used here for comparison.

F.3.4.1.3 Conversion to Metal

The environmental parameters associated with conversion to metal are very similar to those for U_3O_8 conversion (Table F.21); however, raw water usage for construction and normal operation would be about 50% higher. If the construction water was obtained from a nearby river, the rate of withdrawal would be negligible compared to average flows (less than 0.001%). For normal operations, the increased rate of withdrawal would produce an impact less than 0.005% of the average flows. If the construction water and water for normal operations were obtained from wells, there would be no impacts on surface water.

As was the case for the conversion to U_3O_8 and UO_2 options, discharge waters would receive either 0.001 or 0.002 Ci/yr. For the water discharges listed in Table F.21, the equivalent concentrations would range from 25 to 53 μg/L. After dilution in nearby surface waters, the concentrations would be much less than the EPA proposed drinking water standard for uranium, used here for comparison.

F.3.4.1.4 Cylinder Treatment

Construction and operation of the cylinder treatment facility would use less land and water and produce less wastewater than the construction and operation of conversion facilities, as shown in Table F.22. Thus, potential impacts would be smaller. There are no postulated accidents that would directly release contaminants to surface water (LLNL 1997).

TABLE F.22 Summary of Environmental Parameters for the Cylinder Treatment Facility

Parameter	Unit	Construction	Operations	Accidents
Land area	acres	8.7	–	None
Disturbed land	acres	4.5	–	None
Water	million gal/yr	3.6	3.4	None
Wastewater[a]	million gal/yr	1.3	2.3	None

[a] Includes sanitary wastewater, cooling tower blowdown, industrial water, and process water.

F.3.4.2 Groundwater

The methodology for assessing impacts to groundwater for each conversion technology is described in detail in Appendix C and Tomasko (1997).

F.3.4.2.1 Conversion to U_3O_8

Potential impacts to groundwater could occur during construction, normal operations, and postulated accident scenarios. These impacts include the following: changes in effective recharge to underlying aquifers; changes in the depth to groundwater; changes in the direction of groundwater flow; and changes in groundwater quality.

If construction water were supplied from underlying aquifers, approximately 15 gpm would be withdrawn. This withdrawal represents a maximum 0.1% increase in extraction over that at representative facilities and would produce a negligible impact on the groundwater system. If the construction water were obtained from surface water, there would be no groundwater impacts. Groundwater quality could also be impacted by construction activities. For example, exposed chemicals could be mobilized by precipitation and infiltrate the surficial aquifers. By following good engineering and construction practices (e.g., covering chemicals to prevent interaction with rainfall, promptly cleaning up any chemical spills, and providing retention basins to catch and hold any contaminated runoff), groundwater concentrations would be less than the EPA guidelines.

Normal operations of the conversion facility would require about 65 gpm of raw water (Table F.21). If pumped from wells in the surficial aquifers, the impact would be negligible (0.5% increase in extraction). If withdrawn from nearby surface water, there would be no impact on groundwater. Because discharges to groundwater are not planned for normal operations, there would be no direct impacts to groundwater quality. Potential impacts could be derived from interaction with surface water; however, because impacts to surface water are negligible, impacts to groundwater via a surface water pathway would be even less.

As discussed in Section F.3.4.1.1, only one accident scenario, the HF pipeline break, would potentially release contaminants to the groundwater (Table F.21). Because of rapid mitigation and the small volume of HF in the release, this scenario would have a negligible impact on groundwater quality and would not affect recharge, depth to groundwater, or direction of flow.

F.3.4.2.2 Conversion to UO_2

The environmental parameters associated with the UO_2 conversion alternatives are very similar to those for U_3O_8 conversion (Table F.21), except for raw water use during normal operations (about five times larger). If water were obtained from underlying aquifers, pumping would represent an increase of about 5% of the current groundwater use. These impacts would be negligible.

F.3.4.2.3 Conversion to Metal

The environmental parameters associated with the metal conversion alternatives are very similar to those for U_3O_8 conversion (Table F.21), except for a 50% increase in raw water use during construction and normal operations. If the water for construction and normal operations was obtained from underlying aquifers, pumping would increase by 0.15% above current usage during construction, and by 0.8% of the current use for normal operations. These impacts would be negligible. If the water needed for construction and operations was obtained from surface water, there would be no impacts to groundwater.

During construction, groundwater concentrations would be kept below EPA guidelines (EPA 1996) by following good engineering practices. During normal operations, there would be no impacts to groundwater quality because direct discharges to groundwater are not planned.

F.3.4.2.4 Cylinder Treatment Facility

For the cylinder treatment facility, there would be no direct impacts to groundwater during normal operations because groundwater would not be used to supply the water required (Table F.22) and there would be no discharges of wastewater to the ground. Impacts to groundwater during construction of the cylinder treatment facility include changes in effective recharge, changes in the depth to the water table, changes in the direction of groundwater flow, and changes in quality.

Construction of the cylinder treatment facility would decrease the permeability of about 4.5 acres (1.8 ha) of land because of paving and building. This loss of permeable land would reduce recharge, increase the depth to the water table, and change the direction of groundwater flow; however, because the area affected would be small (about 0.1 to 0.3% of the land area available), these impacts would be negligible and limited to small, local regions in the immediate vicinity of the paved lots and building footprints.

During construction, groundwater quality would also be impacted. For example, stockpiled chemicals could be mobilized by precipitation and infiltrate the surficial aquifers. By following good engineering and construction practices (e.g., covering chemicals to prevent interaction with rain, promptly cleaning up any chemical spills, and providing retention basins to catch and hold any contaminated runoff), groundwater concentrations would be less than the EPA guidelines.

F.3.4.3 Soil

The methodology for estimating potential impacts to soil is described in detail in Appendix C and Tomasko (1997).

F.3.4.3.1 Conversion to U_3O_8

Potential impacts to soil could occur during construction, normal operations, and postulated accident scenarios. These impacts include changes in topography, permeability, quality, and erosion potential. The impacts are evaluated over a range of conditions present at the representative sites and are also applicable for a similarly sized generic site located in the vicinity of a major river.

Paving and construction would alter about 13 acres (5.3 ha) and potentially disturb up to 20 acres (8.1 ha) (LLNL 1997). Soil beneath the buildings and paved areas may be altered permanently. Although the alteration of these lands might be permanent, the net impact would be negligible in comparison to the representative land areas involved (ranging from 0.3 to 0.8% of the land area available). A larger range of values is associated with the potential land area disturbed (ranging from 0.5 to 1.2% of the land area available). These impacts could include increased permeability, modification of the local topography, changes in the soil chemistry, and increases in the potential for soil erosion. These impacts would, however, be insignificant on a sitewide scale. In addition, impacts to these areas would be mitigated with time (e.g., disturbed soil would be regraded to natural contours and seeded with natural vegetation, thereby returning the soils to their original condition).

By following good engineering practices (e.g., disturbing as little soil as possible, contouring and reseeding disturbed lands, scheduling construction activities to minimize land disturbance, controlling runoff, using tarps to prevent chemical/precipitation interactions, and cleaning up any spills as soon as they occurred), negligible impacts to soils should occur.

Because normal operations would not affect soil, there would be no soil impacts. The only accident identified that could potentially impact the soil is an HF pipeline rupture (Table F.21), discussed in Section F.3.4.1.1. Because of rapid mitigation (any contaminated soil would be cleaned up within 48 hours of the rupture) and the small release volume (60 gal of HF), impacts to the soil would be negligible.

F.3.4.3.2 Conversion to UO_2

The environmental parameters associated with the UO_2 conversion alternatives are very similar to those for U_3O_8 conversion (Table F.21). Because of these similarities, impacts to soil for UO_2 conversion would be negligible.

F.3.4.3.3 Conversion to Metal

The environmental parameters associated with the metal conversion alternatives are very similar to those for U_3O_8 conversion (Table F.21). Because of these similarities, impacts to soils would be essentially the same as those previously presented, i.e., none to negligible.

F.3.4.3.4 Cylinder Treatment Facility

For the cylinder treatment facility, the only impacts would occur during construction. There would be no discharges to the ground under normal operations, and there are no accidents identified in LLNL (1997) that would lead to direct contamination of the soil. Impacts from construction would include changes in topography, permeability, quality, and erosion potential. By following good engineering and construction practices (e.g., covering chemicals with tarps, cleaning up chemical spills as soon as they occur, and providing retention basins to catch and hold any contaminated surface runoff), impacts to soil quality would be negligible.

F.3.5 Socioeconomics

The impact of each conversion option on socioeconomic activity was estimated for a region of influence (ROI) at the three representative sites. The assessment methodology is discussed in Appendix C and Allison and Folga (1997).

Each of the conversion options is likely to have a small impact on socioeconomic conditions in the ROIs surrounding the three representative sites described in Chapter 3, Sections 3.1.8, 3.2.8, and 3.3.8. This is largely because a major proportion of the expenditures associated with procurement for the construction and operation of each technology option flows outside the ROI to other locations in the United States, reducing the concentration of local economic effects of each conversion option.

Slight changes in employment and income would occur in each ROI as a result of local spending of personal consumption expenditures derived from employee wages and salaries, local procurement of goods and services required to construct and operate each conversion option, and other local investment associated with construction and operation. In addition to creating new (direct) jobs at each site, each conversion option would also create indirect employment and income in the ROI as a result of jobs and procurement expenditures at each site. Jobs and income created directly by each conversion option, together with indirect activity in the ROI, would contribute slightly to reduction in unemployment in the ROI surrounding each site. Minimal impacts are expected on local population growth, and consequently on local housing markets and local fiscal conditions.

The effects of constructing and operating each conversion technology on regional economic activity (measured in terms of employment and personal income) and on population, housing, and local public revenues and expenditures are described in Sections F.3.5.1 through F.3.5.4. Impacts are presented as ranges to include impacts that would occur with each conversion option and for the cylinder treatment facility at each of the representative sites. Impacts for the three sites are presented for the peak year of construction (assumed to be 2006) and the first year of operations (assumed to be 2009). The potential impacts for each conversion option and for the cylinder treatment facility are presented in Table F.23.

F.3.5.1 Conversion to U_3O_8

During the peak year of construction of a U_3O_8 conversion facility, between 240 and 250 direct jobs would be created at the site and 170 to 330 additional jobs would be created indirectly in the site ROI (Table F.23) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 410 to 580 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with total income ranging from $14 million to $17 million during the peak year. During the first year of operations of the U_3O_8 conversion facility, 440 to 510 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROIs, with total income ranging from $14 million to $15 million. Construction and operation of the conversion facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 to 0.05 percentage points from 1999 through 2028.

Construction of the U_3O_8 conversion facility would be expected to generate direct in-migration of 330 to 340 people in the peak year of construction at the site. Additional indirect job in-migration would also be expected in the site ROIs, bringing the total number of in-migrants to between 410 and 470 in the peak year (Table F.23). Operation of the U_3O_8 conversion facility would be expected to generate direct and indirect job in-migration of 220 to 340 in the first year of

TABLE F.23 Potential Socioeconomic Impacts of the Conversion Options

	Conversion to U_3O_8		Conversion to UO_2	
	Construction[a]	Operations[b]	Construction[a]	Operations[b]
Economic activity in the ROI				
Direct jobs	240 – 250	200 – 210	330 – 630	230 – 360
Indirect jobs	170 – 330	240 – 300	230 – 730	310 – 920
Total jobs	410 – 580	440 – 510	560 – 1,400	500 – 1,300
Income ($ million)				
Direct income	11	10	15 – 28	11 – 18
Total income	14 – 17	14 – 15	19 – 42	16 – 28
Population in-migration into the ROI	410 – 470	220 – 340	570 – 1,200	210 – 1,100
Housing demand				
Number of units in the ROI	150 – 170	80 – 130	210 – 440	80 – 390
Public finances				
Change in ROI fiscal balance (%)	0.1 – 0.3	<0.1 – 0.2	0.1 – 0.7	<0.1 – 0.6
	Conversion to Uranium Metal		**Cylinder Treatment Facility**	
	Construction[a]	Operations[b]	Construction[a]	Operations[b]
Economic activity in the ROI				
Direct jobs	380 – 440	210 – 370	100	130
Indirect jobs	230 – 470	310 – 520	40 – 80	130 – 180
Total jobs	610 – 910	520 – 890	150 – 180	260 – 310
Income ($ million)				
Direct income	12 – 16	10 – 18	5	10
Total income	15 – 25	15 – 27	5 – 6	13 – 14
Population in-migration into the ROI	650 – 790	240 – 630	160 – 180	240 – 300
Housing demand				
Number of units in the ROI	240 – 290	90 – 230	60 – 70	90 – 110
Public finances				
Change in ROI fiscal balance (%)	0.1 – 0.5	<0.1 – 0.4	<0.0 – 0.1	<0.0 – 0.2

[a] Impacts are for the peak year of construction, 2007. Socioeconomic impacts were assessed for 1999 through 2008.

[b] Impacts are the annual averages for operations for the period 2009 through 2028.

operations. Construction and operation of the facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of less than 0.01 to 0.04 percentage points from 1998 through 2028.

A U_3O_8 conversion facility would generate a demand for 150 to 170 additional rental housing units during the peak year of construction (Table F.23), representing an impact of 2.7-11% on the projected number of vacant rental housing units in the representative site ROIs. A demand for 80 to 130 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.7 to 2.7% on the number of vacant owner-occupied housing units in the ROIs.

During the peak year of construction, 410 to 470 people would be expected to in-migrate into the ROI at the site, leading to increases of between 0.1 and 0.3% over forecasted baseline revenues and expenditures in the representative site ROI (Table F.23). In the first year of operations, 220 to 340 in-migrants would be expected, leading to increases of less than 0.1 to 0.2% in local revenues and expenditures.

F.3.5.2 Conversion to UO_2

During the peak year of construction of a UO_2 conversion facility, 330 to 630 direct jobs would be created at the site and 230 to 730 additional jobs indirectly in the site ROI (Table F.23) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 560 to 1,400 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with total income ranging from $19 million to $42 million during the peak year. During the first year of operations of the UO_2 conversion facility, 540 to 1,200 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with total income ranging from $16 million to $28 million. Construction and operation of the conversion facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 to 0.1 percentage points from 1999 through 2028.

Construction of the UO_2 conversion facility would be expected to generate direct in-migration of 460 to 860 people in the peak year of construction at the site. Additional indirect job in-migration would also be expected in the site ROIs, bringing the total number of in-migrants to between 570 and 1,200 in the peak year (Table F.23). Operation of the UO_2 conversion facility would be expected to generate direct and indirect job in-migration of 210 to 1,100 in the first year of operations. Construction and operation of the facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of less than 0.01 to 0.06 percentage points from 1999 through 2028.

The UO_2 conversion facility would generate a demand for 210 to 440 additional rental housing units during the peak year of construction, representing an impact of 3.8 to 28% on the projected number of vacant rental housing units in the representative site ROIs (Table F.23). A demand for 80 to 390 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.7 to 8.2% on the number of vacant owner-occupied housing units in the ROIs.

During the peak year of construction, 570 to 1,200 people would be expected to in-migrate into the ROI at the site, leading to increases of 0.1 to 0.7% over forecasted baseline revenues and expenditures in the representative site ROIs (Table F.23). In the first year of operations, 210 to 1,100 in-migrants would be expected, leading to increases of less than 0.1 to 0.6% in local revenues and expenditures.

F.3.5.3 Conversion to Metal

During the peak year of construction of a metal conversion facility, 380 to 440 direct jobs would be created at the site and 230 to 470 additional jobs indirectly in the site ROI (Table F.23) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 610 to 910 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with total income ranging from \$15 million to \$25 million during the peak year. During the first year of operations of the metal conversion facility, 520 to 890 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with total income ranging from \$15 million to \$27 million. Construction and operation of the conversion facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 to 0.09 percentage points from 1999 through 2028.

Construction of the metal conversion facility would be expected to generate direct in-migration of 520 to 600 people in the peak year of construction at the site. Additional indirect job in-migration would also be expected in the site ROI, bringing the total number of in-migrants to between 650 and 790 in the peak year (Table F.23). Operation of the metal conversion facility would be expected to generate direct and indirect job in-migration of 240 to 630 in the first year of operations. Construction and operation of the facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.01 to 0.08 percentage points from 1999 through 2028.

The metal conversion facility would generate a demand for 240 to 290 additional rental housing units during the peak year of construction, representing an impact of 4.3 to 18.5% on the projected number of vacant rental housing units in the representative site ROIs (Table F.23). A demand for 90 to 230 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.8 to 4.9% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of construction, 650 to 790 people would be expected to in-migrate into the ROI surrounding the site, leading to increases of 0.1 to 0.5% over forecasted baseline revenues and expenditures in the representative site ROIs (Table F.23). In the first year of operations, 240 to 630 in-migrants would be expected, leading to increases of less than 0.1 to 0.4% in local revenues and expenditures.

F.3.5.4 Cylinder Treatment Facility

During the peak year of construction of a cylinder treatment facility, approximately 100 direct jobs would be created at the site and 40 to 80 additional jobs indirectly in the site ROI (Table F.23) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 150 to 180 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with total income ranging from $5 million to $6 million during the peak year. During the first year of operations of the cylinder treatment facility, 260 to 310 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, with total income ranging from $13 million to $14 million. Construction and operation of the facility would result in an increase in the projected baseline compound annual average growth rate in ROI employment of 0.01 to 0.03 percentage points from 1999 through 2028.

Construction of the cylinder treatment facility would be expected to generate direct in-migration of 140 people in the peak year of construction at the site. Additional indirect job in-migration would also be expected in the site ROI, bringing the total number of in-migrants to between 160 and 180 in the peak year (Table F.23). Operation of the cylinder treatment facility would be expected to generate direct and indirect job in-migration of 240 to 300 in the first year of operations. Construction and operation of the facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of less than 0.01 to 0.02 percentage points from 1999 through 2028.

The cylinder treatment facility would generate a demand for 60 to 70 additional rental housing units during the peak year of construction, representing an impact of 1.1 to 4.4% on the projected number of vacant rental housing units in the representative site ROIs (Table F.23). A demand for 90 to 110 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.8 to 2.3% on the number of vacant owner-occupied housing units in the ROI.

During the peak year of construction, 160 to 180 people would be expected to in-migrate into the ROI surrounding the site, leading to increases of 0.0 to 0.1% over forecasted baseline revenues and expenditures in the representative site ROIs (Table F.23). In the first year of operations, 240 to 300 in-migrants would be expected, leading to increases of less than 0.1 to 0.2% in local revenues and expenditures.

F.3.6 Ecology

Moderate impacts to ecological resources could result from construction of a conversion facility. Impacts could include mortality of individual organisms, habitat loss, or changes in biotic communities. Impacts due to operation of a conversion facility would be negligible. Potential impacts to vegetation, wildlife, wetlands, and threatened and endangered species were assessed. The methodology used in the ecological impact analysis is discussed in Appendix C.

F.3.6.1 Conversion to U_3O_8

Site preparation for the construction of a facility to convert UF_6 to U_3O_8 would require the disturbance of approximately 20 acres (8 ha), including the permanent replacement of approximately 13 acres (5.3 ha) with structures and paved areas. Existing vegetation would be destroyed during land clearing activities. Determination of the vegetation communities that would be eliminated by site preparation would depend on the future location of the facility. Communities occurring on undeveloped land at the three representative sites are relatively common and well represented in the vicinity of the sites. Impacts to high-quality native plant communities may occur if facility construction requires disturbance to vegetation communities outside of the currently fenced areas (see Section F.3.9 for a discussion of land use). Construction of the conversion facility would not be expected to threaten the local population of any species. The loss of up to 20 acres (8 ha) of undeveloped land would constitute a moderate adverse impact. Erosion of exposed soil at construction sites could reduce the effectiveness of restoration efforts and create sedimentation downgradient of the site. The implementation of standard erosion control measures, installation of storm-water retention ponds, and immediate replanting of disturbed areas with native species would help minimize impacts to vegetation. Impacts due to facility construction are shown in Table F.24.

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land clearing activities. More mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities, and thus competition for food and nesting sites, would increase in these areas, potentially reducing the survivability or reproductive capacity of displaced individuals. Many wildlife species would be expected to quickly recolonize replanted areas near the conversion facility following completion of construction. The permanent loss of up to 13 acres (5.3 ha) of habitat would not be expected to threaten the local population of any wildlife species because similar habitat would be available in the vicinity of the sites. Therefore, construction of a conversion facility for U_3O_8 production would be considered a moderate adverse impact to wildlife.

Impacts to surface water and groundwater quality during construction are expected to be negligible (Section F.3.4). Thus, construction-derived impacts to aquatic biota would also be expected to be negligible. Wetlands could potentially be impacted by filling or draining during construction. Impacts to wetlands due to alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur if the conversion facility were located immediately adjacent to

TABLE F.24 Impacts to Ecological Resources from Construction of a Conversion Facility and Cylinder Treatment Facility

Option/Resource	Type of Impact	Degree of Impact
Conversion to U_3O_8		
Vegetation	Loss of 20 acres	Moderate adverse impact
Wildlife	Loss of 13 to 20 acres	Minor to moderate adverse impact
Wetlands	Loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Negligible impact
Protected species	Destruction, habitat loss	Potential adverse impact
Conversion to UO_2		
Vegetation	Loss of 22 to 31 acres	Moderate adverse impact
Wildlife	Loss of 14 to 31 acres	Moderate adverse impact
Wetlands	Loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Negligible impact
Protected species	Destruction, habitat loss	Potential adverse impact
Conversion to metal		
Vegetation	Loss of 23 to 26 acres	Moderate adverse impact
Wildlife	Loss of 15 to 26 acres	Moderate adverse impact
Wetlands	Loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Negligible impact
Protected species	Destruction, habitat loss	Potential adverse impact
Cylinder treatment facility		
Vegetation	Loss of 9 acres	Moderate adverse impact
Wildlife	Loss of 5 to 9 acres	Moderate adverse impact
Wetlands	Loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Negligible impact
Protected species	Destruction, habitat loss	Potential adverse impact

wetland areas. However, impacts to wetlands would be minimized by maintaining a buffer area around wetlands during construction of the facility. Unavoidable impacts to wetlands would require a *Clean Water Act* Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies.

Critical habitat has not been designated for any state or federally listed threatened or endangered species at any of the representative sites. Prior to construction of a conversion facility, a site-specific survey for federal- and state-listed threatened, endangered, or candidate species or species of special concern would be conducted. Impacts to these species could thus be avoided or, where impacts were unavoidable, appropriate mitigation could be developed.

During operations, ecological resources in the vicinity of the conversion facility would be exposed to atmospheric emissions from the boiler stack and process stack; however, emission levels would be expected to be extremely low (Section F.3.3.2). The highest annual average air concentration of U_3O_8 at a representative site boundary would be less than 2.6×10^{-5} µg/m³. This would result in a radiation exposure to the general public (nearly 100% due to inhalation) of less than 0.009 mrem/yr (Section F.3.1.1), well below the DOE guidelines of 100 mrem/yr (0.00027 rad/d). Wildlife species are less sensitive to radiation than humans (proposed DOE guidelines would require an absorbed dose limit to terrestrial animals of 0.1 rad/d). Therefore, impacts to wildlife due to radiation effects would be expected to be negligible. Toxic effects of chronic inhalation of U_3O_8 are minor at a concentration of 17 mg/m³ for tested animal species. This is many orders of magnitude greater than expected emissions. Therefore, toxic effects to wildlife due to U_3O_8 inhalation would also be expected to be negligible. See Appendix C for further discussion.

The maximum annual average air concentration of hydrogen fluoride at a site boundary, due to operation of a conversion facility, would be less than 0.0073 µg/m³ (Section F.3.3.2). Chronic exposure to HF gas produces only mild effects in tested animal species at concentrations as high as 7 mg/m³, considerably higher than expected emissions. Therefore, toxic effects to wildlife from HF emissions would be expected to be negligible.

A portion of the U_3O_8 released from the process stack of a conversion facility would become deposited on the soils surrounding the site. Uptake of uranium-containing compounds can cause adverse effects to vegetation. Deposition of U_3O_8 on soils, resulting from atmospheric emissions, would result in soil uranium concentrations considerably below the lowest concentration known to produce toxic effects in plants. Therefore, toxic effects on vegetation due to U_3O_8 uptake would be expected to be negligible.

Effluent discharges to surface waters would result in a uranium concentration of about 12 pCi/L (0.03 mg/L) as uranyl nitrate (Section F.3.4.1). Resulting dose rates to maximally exposed organisms would be considerably lower than the dose limit of 1 rad/d for aquatic organisms, which is required by DOE Order 5400.5. Uranyl nitrate concentrations in the effluent also would be considerably lower than 0.15 mg/L, the lowest concentration known to cause toxic effects in aquatic biota. Mixing of the effluent with surface water downstream of the outfall would result in a dilution factor of more than 50,000. Therefore, impacts to aquatic biota would be considered to be negligible.

For the U_3O_8 conversion process, water withdrawal from surface waters or groundwater, as well as wastewater discharge, could potentially alter water levels which could in turn affect aquatic ecosystems including wetlands (including wetlands located along the periphery of these surface water bodies). However, water level changes due to process water withdrawal and wastewater discharge would be negligible (Section F.3.4.1). Therefore, impacts to wetlands would be expected to be negligible.

A potential release of contaminants due to the occurrence of an earthquake was analyzed. The subsequent rupture of an HF pipeline would potentially release anhydrous HF into the surrounding soil, surface water, or groundwater. Due to the brief duration of the release, the small volume involved, and rapid mitigation, the expected impacts to surface water, groundwater, and soil would be negligible (Section F.3.4). Therefore, impacts to ecological resources from such an accident would also be expected to be negligible. Facility accidents, as discussed in Section F.3.2, could result in adverse impacts to ecological resources. The affected species and the degree of impact would depend on a number of factors such as location of the accident, season, and meteorological conditions.

F.3.6.2 Conversion to UO_2

The construction of a facility to convert depleted UF_6 to UO_2 would generally result in the types of impacts associated with conversion to U_3O_8. Site preparation for the construction of a facility to convert depleted UF_6 to UO_2 would require the disturbance of approximately 22 to 31 acres (8.9 to 12.5 ha), including the permanent replacement of approximately 14 to 19 acres (5.5 to 7.8 ha) with structures and paved areas. The loss of 22 to 31 acres (8.9 to 12.5 ha) of undeveloped land would constitute a moderate adverse impact to vegetation. The permanent loss of up to 19 acres (7.8 ha) of habitat would not be expected to threaten the local population of any wildlife species because similar habitat would be available in the vicinity of the representative sites. However, habitat use in the vicinity of the facility might be greatly reduced for many species due to the construction of a perimeter fence. Consequently, the construction of a conversion facility for UO_2 production is considered a moderate adverse impact to wildlife.

Impacts to surface water and groundwater quality during construction would be expected to be negligible (Section F.3.4). Thus, construction-derived impacts to aquatic biota would also be expected to be negligible. Impacts to wetlands and protected species due to facility construction would be similar to impacts associated with conversion to U_3O_8.

During operations, exposures to contaminants from conversion to UO_2 would generally be slightly larger than for conversion to U_3O_8, but all exposures would be well below levels that might produce adverse effects. All impacts would therefore be negligible. Impacts to ecological resources from accident scenarios would be as discussed for conversion to U_3O_8 (Section F.3.6.1).

F.3.6.3 Conversion to Metal

Construction of a facility to convert depleted UF_6 to uranium metal would generally result in the types of impacts associated with conversion to U_3O_8. Site preparation would require the disturbance of approximately 23 to 26 acres (9.4 to 11 ha), including the permanent replacement of about 15 to 16 acres (6.2 to 6.5 ha) with structures and paved areas. The loss of 23 to 26 acres (9.4

to 11 ha) of undeveloped land would constitute a moderate adverse impact to vegetation and wildlife. Impacts due to facility construction are shown in Table F.24.

During operation of the metal conversion facility, exposure to contaminants would be considerably below levels known to cause toxic effects in biota. The resulting impacts would therefore be negligible. Impacts to ecological resources from accidents would be as discussed for conversion to U_3O_8 (Section F.3.6.1).

Construction of a cylinder treatment facility would generally result in the types of impacts associated with construction of a conversion facility; however, the area affected would be smaller (Table F.24). Site preparation for constructing a cylinder treatment facility would require the disturbance of approximately 9 acres (4 ha). About 5 acres (2 ha) would be permanently replaced with structures, paved areas, and landscaping. The loss of 9 acres (4 ha) of undeveloped land would constitute a moderate adverse impact to vegetation and wildlife. Exposure to contaminants resulting from operation of a cylinder treatment facility would be considerably below levels known to result in toxic effects to biota. The resulting impacts would therefore be negligible.

F.3.7 Waste Management

Impacts on waste management from wastes generated during construction and normal operations at the depleted UF_6 conversion facilities would be caused by the potential overload of waste treatment and/or disposal capabilities either at a site or on a regional/national scale. The types of wastes that are expected to be generated by the depleted UF_6 conversion include low-level radioactive waste (LLW), low-level mixed waste (LLMW), hazardous waste, nonhazardous solid waste, and nonhazardous wastewater. Currently, there are numerous DOE and commercial facilities that treat and/or dispose of LLW, hazardous waste, nonhazardous solid waste, and wastewaters. The treatment/disposal of LLMW is limited by regulatory and technological restrictions.

F.3.7.1 Conversion to U_3O_8

Construction of a facility to convert UF_6 into U_3O_8 would generate both hazardous and nonhazardous wastes. Approximately 115 m^3 of hazardous waste, 700 m^3 of nonhazardous solid waste, and 15,000 m^3 of wastewater would be generated during construction (see Table F.25). This compares with existing contributions for hazardous waste ranging from approximately 80 m^3/yr to 1,000 m^3/yr, solid waste loads for the representative sites of 2,100 to 28,000 m^3/yr, and wastewater loads of 500,000 to 880,000 m^3 annually for the representative sites (see Appendix C, Table C.3). No radioactive waste would be generated during the construction phase of the facility. Overall, only minimal waste management impacts would result from construction-generated wastes.

Operations at the facility to convert UF_6 into U_3O_8 would generate radioactive, hazardous, and nonhazardous wastes (Table F.25). The conversion facility would generate 140 to 600 m^3/yr of

TABLE F.25 Wastes Generated from Construction and Operations Activities for Depleted UF_6 Conversion[a]

Activity/ Waste Category	Volume Ranges for the Options		
	Conversion to U_3O_8	Conversion to UO_2	Conversion to Metal
Construction[a] (m^3)			
Low-level waste	–	–	–
Low-level mixed waste	–	–	–
Hazardous waste	115	140 – 200	140 – 180
Nonhazardous waste			
Solids	700	1,300	860 – 1,130
Wastewater	3,800	7,600	5,700 – 7,580
Sanitary wastewater	11,400	17,000	13,200 – 15,200
Operations (m^3/yr)			
Low-level waste			
Combustible waste	76.5	88.0 – 136	76.5 – 420
Noncombustible	62 – 68.2	82.0 – 140	112 – 470
Grouted	0 – 466	0 – 466	0 – 997
Total	140 – 600	170 – 740	190 – 1,890
Low-level mixed waste	1.1	1.1 – 8.8	1.1
Hazardous waste	7.32	7.32 – 17	7.32 – 9.5
Nonhazardous waste			
Solids	380 – 11,000[b]	520 – 30,600[b]	6,580 – 6,840[c]
Wastewater	58,000 – 87,100	74,900 – 510,000	94,000 – 96,500
Sanitary wastewater	4,540 – 4,920	5,680 – 8,700	5,300 – 8,700

[a] Total waste generated during construction period of 4 years.

[b] Includes 240 to 10,630 m^3 of CaF_2.

[c] Includes 67 m^3 of CaF_2 and 5,850 to 6,110 m^3 of MgF_2.

LLW, which, at the upper end, represents approximately 7 to 27% of the representative site LLW loads (see Appendix C, Table C.3). The U_3O_8 conversion facility waste input would represent less than 1% of DOE LLW generation. The U_3O_8 conversion facility would generate approximately 1.1 m^3/yr of LLMW, which is less than 1% of the LLMW generation at the representative sites (ranging from 100 to 5,000 m^3/yr LLMW) (see Appendix C, Table C.3). The U_3O_8 conversion facility would generate approximately 7 m^3/yr of hazardous waste, which would result in an increase of about 1 to 10% of the hazardous waste loads at the representative sites; and about 60,000 to

90,000 m^3/yr of wastewater, representing between 9 and 17% of the current loads for wastewater at the representative sites.

The CaF_2 potentially produced in the U_3O_8 conversion process was assumed to have a uranium content of less than 1 ppm (LLNL 1997). It is currently unknown whether this CaF_2 could be sold (e.g., as feedstock for commercial production of anhydrous HF) or whether the low uranium content would require disposal as either a nonhazardous solid waste or as LLW. The nonhazardous solid waste generation estimates for conversion to U_3O_8 and UO_2, as shown in Table F.25, are based on the assumption that CaF_2 would be disposed of as nonhazardous solid waste, generating approximately 380 to 11,000 m^3/yr of nonhazardous solid waste (from 18 to 500% of the current nonhazardous solid waste loads at the representative sites, depending on the conversion technology chosen). If CaF_2 were considered to be LLW, it would represent an additional 3 to 480% of the current LLW loads at the representative sites. The upper end of the range of nonhazardous and LLW volume increases (which correspond to the HF neutralization process) would constitute a potentially large impact to either nonhazardous or LLW management activities at an actual site. Disposal as LLW might require the CaF_2 to be grouted, generating up to 21,300 m^3/yr of grouted waste. The maximum volume of LLW generated would still represent less than 10.4% of the projected DOE complexwide LLW disposal volume, constituting a moderate impact with respect to complexwide LLW management. It is also unknown whether CaF_2 LLW would be considered DOE waste if the conversion were conducted by a private commercial enterprise. If CaF_2 could be sold, the nonhazardous solid waste or LLW management impacts would be reduced to a low level for U_3O_8 conversion technologies.

The impacts from normal operation of the U_3O_8 conversion facility would range from negligible to large, depending upon the choice of technology and the ultimate generation volumes and disposition of CaF_2 for the facility. Overall, the waste input resulting from normal operations at the U_3O_8 conversion facility would be expected to have a moderate impact on waste management. If CaF_2 were disposed of as nonhazardous solid waste, the increased input could be managed by expanding the capacity of the nonhazardous solid waste disposal facilities at the actual site.

F.3.7.2 Conversion to UO_2

Construction of a facility to convert UF_6 into UO_2 would generate approximately the same quantity of hazardous wastes as conversion to U_3O_8. Construction would generate approximately 1,300 m^3 of solid nonhazardous wastes and up to 24,000 m^3 of wastewater (see Table F.25). These waste loads are well below the representative site waste inputs for comparable wastes. No radioactive waste would be generated during the construction phase of the facility. Overall, only minimal waste management impacts would result from construction-generated wastes.

Operations at the facility to convert UF_6 into UO_2 would generate radioactive, hazardous, and nonhazardous wastes (Table F.25). The conversion facility would generate about 9 to 33% of the representative site LLW loads (see Appendix C, Table C.3). The UO_2 conversion facility would generate up to 465 m^3/yr of a solid, grouted LLW that would require off-site disposal. The conversion facility LLW input would represent less than 1% of the projected annual DOE LLW treatment volume. The UO_2 conversion facility would generate from 1 to 9% of the LLMW generation for the representative sites (see Appendix C, Table C.3). The UO_2 conversion facility would generate 7 to 17 m^3/yr of hazardous waste, which would result in a minor increase to the hazardous waste load from routine operations at the representative site. The UO_2 conversion facility would add 520 to 30,600 m^3/yr of nonhazardous solid waste and about 80,000 to 500,000 m^3/yr of wastewater (see Table F.25).

As in the U_3O_8 conversion option, it is currently unknown whether CaF_2 generated in the conversion to UO_2 option could be sold or whether the low uranium content (less than 1 ppm) would require disposal as either a nonhazardous solid waste or as LLW. The nonhazardous solid waste generation estimates for conversion to UO_2 shown in Table F.25 are based on the assumption that CaF_2 would be disposed of as nonhazardous solid waste, generating about 240 to 11,000 m^3/yr of nonhazardous solid waste (up to 500% of the current nonhazardous solid waste loads at the representative sites, depending on the conversion technology chosen). If CaF_2 were considered to be LLW, it would represent up to 480% of the current LLW loads at the representative sites. The upper end of the range of nonhazardous and LLW volume increases (which correspond to the HF neutralization process) would constitute a potentially large impact to either nonhazardous or LLW management activities at an actual site. Disposal as a LLW might require the CaF_2 to be grouted, generating up to 21,300 m^3/yr of grouted waste. However, the maximum volume of LLW generated would still represent less than 10.4% of the projected DOE complexwide LLW disposal volume, constituting a moderate impact with respect to complexwide LLW management, if the CAF_2 were considered DOE waste. If CaF_2 could be sold, the nonhazardous solid waste or LLW management impacts would be reduced to a low level for UO_2 conversion technologies.

The large range in the expected volume of nonhazardous solid waste and wastewater is also a result of differences in UO_2 conversion technologies. The gelation technology would result in the highest nonhazardous waste generation volumes. The range of 520 to 30,600 m^3/yr for nonhazardous solid wastes represents an approximate range of 2 to 1,500% (15 times) the annual nonhazardous solid waste production at the representative sites. The estimated range for wastewater generation represents a range of about 13 to 115% of the annual wastewater generation at the representative sites.

The impacts from normal operation of the UO_2 conversion facility would range from negligible to large, depending upon the choice of technology for this facility. Overall, the waste input resulting from normal operations at the UO_2 conversion facility would be expected to have a moderate impact on waste management. The increased solid waste input could be managed by expanding the capacity of the solid nonhazardous waste disposal facilities at the sites. The increased wastewater input would be handled by existing site wastewater capabilities of the representative sites.

F.3.7.3 Conversion to Metal

Construction of the facility to convert UF_6 into uranium metal would generate approximately the same quantity of hazardous and nonhazardous wastes as conversion to U_3O_8 or UO_2 (Table F.25). No radioactive waste would be generated during the construction phase of the facility. Overall, only minimal waste management impacts would result from construction-generated wastes.

Operations at the facility to convert UF_6 into uranium metal would generate radioactive, hazardous, and nonhazardous wastes (Table F.25). The conversion facility would generate about 23 to 85% of the representative site LLW loads (see Appendix C, Table C.3). A metal conversion facility LLW input would represent less than 3% of the projected annual DOE LLW treatment volume. The metal conversion facility would generate less than 1% of the LLMW generation at the representative sites (see Appendix C, Table C.3) and less than 12% of the hazardous waste load from routine operations at the three representative sites. The metal conversion facility would add from 25 to 325% of the existing representative site solid waste load and from 12 to 20% of the load for wastewater. The increased solid waste input could be managed by expanding the disposal capacity of the solid nonhazardous waste disposal facilities at the actual site.

It is possible that the MgF_2 waste generated in the conversion to metal option would be sufficiently contaminated with uranium to require disposal as LLW rather than as solid nonhazardous waste. The uranium level in the MgF_2 is estimated to be about 90 ppm (LLNL 1997). Such disposal might require the MgF_2 waste to be grouted, generating about 6,150 to 12,300 m^3/yr of grouted waste for LLW disposal. This volume range represents about 72 to 560% of the current LLW generation for the representative three sites (see Appendix C, Table C.3). However, it would represent less than 6% of the projected DOE complexwide LLW disposal volume, constituting a low impact with respect to complexwide LLW management, if the MgF_2 were considered a DOE waste.

Neutralization of HF to CaF_2 was not explicitly analyzed in the engineering analysis report for the conversion to metal options (LLNL 1997). However, the process could be implemented and would produce approximately one-third as much CaF_2 as would be produced under the conversion to oxide with neutralization options (i.e., approximately 3,500 m^3/yr of CaF_2). If this CaF_2 waste were disposed of as LLW, it would constitute less than 3% of the DOE complexwide LLW disposal volume, representing a low impact with respect to complexwide LLW management.

Overall, the waste input resulting from normal operations at the uranium metal conversion facility would have a moderate impact on waste management.

F.3.7.4 Cylinder Treatment Facility

All of the conversion options would require the removal of depleted UF_6 from the storage cylinders, resulting in a large number of empty cylinders. These empty UF_6 cylinders from the conversion facility would be decontaminated at the cylinder treatment facility and then prepared for disposal as scrap metal. It was assumed for this assessment that the cylinder treatment facility would be washing the empty cylinders with water to remove the "heels" of depleted UF_6. The resulting aqueous wash solution would be evaporated and converted to solid U_3O_8 and HF. The U_3O_8 would be packaged and sent for disposal. The HF would be neutralized to CaF_2 and separately packaged for either disposal or sale.

Construction of the cylinder treatment facility would generate both hazardous and nonhazardous wastes. These waste quantities — hazardous, 18 m^3; solid nonhazardous, 300 m^3; and sanitary and other nonhazardous liquids, 28,000 m^3 — all represent only minimal waste management impacts at any of the three potential sites. No radioactive waste would be generated during construction of this facility.

The amounts of waste generated annually during operation of the cylinder treatment facility are given in Table F.26. Included are crushed old cylinders and wastes obtained (U_3O_8 and CaF_2) from disposal of the "heels." All of these wastes, except the crushed old cylinders, represent only negligible impacts to the waste management system. Over 20 years of operations, the crushed old cylinders (2,322 cylinders/yr) would generate about 125,000 m^3 (6,190 m^3/yr × 20 years) of waste volume for disposal. It was assumed that the treated cylinders with a very low residual radiation level

TABLE F.26 Annual Waste Generation during Operation of the Cylinder Treatment Facility

Waste Category	Volume (m^3/yr)
Low-level waste	
Combustible solids	31
Contaminated metal and other noncombustible solids	11
U_3O_8	6.3
Low-level mixed waste	0.2
Hazardous waste	2
Nonhazardous waste	
Solids	100
Wastewater	6,400
CaF_2	14
Sanitary waste	2,300
Crushed cylinders	6,190

would become part of the DOE scrap metal inventory. If a disposal decision were made, the treated cylinders would be disposed of as LLW, representing a 3% addition to the projected DOE complexwide LLW disposal volume.

F.3.7.5 Summary

The impacts from the uranium metal conversion facility would be greater than the waste management impacts resulting from operations of U_3O_8 conversion, unless CaF_2 required disposal as a waste. In the latter case, the impacts to waste management facilities for U_3O_8 conversion would probably exceed those for uranium metal conversion. The largest waste volumes would result from conversion to UO_2.

F.3.8 Resource Requirements

Utilities and materials required for constructing the conversion facility for UF_6 to U_3O_8, UO_2, or uranium metal are listed in Table F.27. The equipment for conversion processes would be purchased from equipment vendors. The total quantities of commonly used materials of construction (e.g, carbon steel, stainless steel) for equipment would be minor compared to the quantities required for facility construction, as listed in Table F.27. The primary specialty materials required for fabricating process equipment include Monel and Inconel (LLNL 1997). Utilities and materials required for operating the three conversion facilities are shown in Table F.28.

F.3.9 Land Use

F.3.9.1 Conversion to U_3O_8

Impacts to land use from the construction and operation of a U_3O_8 conversion facility would be negligible. Such impacts would be limited to the clearing of required land, minor and temporary disruptions to contiguous land parcels, and a slight increase in vehicular traffic. Under this conversion option, a conversion facility would require approximately 20 acres (8 ha) for construction and about 13 acres (5 ha) for operation (see Table F.29). The construction phase requires more land because space is needed for material excavation storage, equipment staging, and construction material laydown areas.

The amount of land required for this conversion option would not be great enough to require major land modification. However, it should be noted that siting a conversion facility at a location that is already dedicated to similar use could result in fewer land-use impacts because immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land use.

TABLE F.27 Resource Requirements for Constructing a Conversion Facility

		Total Consumption		
Utilities/Materials	Unit	Conversion to U_3O_8	Conversion to UO_2	Conversion to Metal
Utilities				
Electricity[a]	MWh	30,000	35,000	35,000 – 45,000
Solids				
Concrete	yd^3	15,000 – 18,000	21,000 – 44,300	20,000 – 23,000
Steel (carbon or mild)	ton	6,000 – 7,000	8,000 – 8,800	9,000 – 10,000
Liquids				
Diesel fuel	million gal	0.75	0.45 – 0.80	0.80 – 1.0
Gasoline	million gal	0.75	0.40 – 0.80	0.80 – 1.0
Gases				
Industrial gases (propane)	gal	4,000	4,400	4,400 – 5,500
Specialty materials				
Monel	ton	15 – 30	25 – 88	20 – 100
Inconel	ton	10	10 – 88	0 – 4
Titanium	ton	NA[b]	0 – 33	0 – 10

[a] The peak electricity demand during any hour would be as follows: conversion to U_3O_8, about 1.5 MW; conversion to UO_2, about 1.5 MW; conversion to metal, from 1.5 to 2.5 MW.

[b] NA = not applicable.

Source: LLNL (1997).

Impacts to land use outside the boundaries of a conversion facility would include negligible and temporary traffic impacts associated with project construction peaks. Also, because of the handling of UF_6 at the facility, NUREG-1140 (McGuire 1985) suggests that a 1-mile protective action distance be established around such a facility, which would cover an area of about 960 acres. The protective action distance is the recommended distance for which emergency planning would be appropriate to mitigate off-site exposure to accidental releases.

F.3.9.2 Conversion to UO_2

Impacts to land use from the UO_2 conversion option would be only slightly greater than those associated with other conversion options. The areal requirements for this option range from

TABLE F.28 Resource Requirements for Operating a Conversion Facility

		Average Annual Requirement		
Utilities/Materials	Unit	Conversion to U_3O_8	Conversion to UO_2	Conversion to Metal
Utilities				
Electricity[a]	GWh	11.0	24 – 29	25 – 44
Liquid fuel	gal	6,000	3,040 – 7,000	6,500 – 9,500
Natural gas	million scf[b]	102 – 118	38 – 116	100 – 167
Solids				
Calcium hydroxide (hydrated lime)	million lb	0.388 – 1.27	0.388 – 1.27	0.247
Calcium oxide (quicklime)	million lb	0 – 29	0 – 29	NA[c]
Cement	lb	0 – 862,000	0 – 862,000	0 – 940,000
Detergent	lb	500	600	600 – 700
Iron	million lb	NA	NA	0 – 1.3
Magnesium	million lb	NA	NA	8.4 – 8.6
Sodium chloride	lb	NA	NA	0 – 514,000
Pelletizing lubricant	lb	NA	236,000	NA
Liquids				
Ammonia	million lb	0 – 0.662	2.9	2.4
Hydrochloric acid	lb	11,100 – 18,200	8,900 – 13,600	5,300 – 9,500
Nitric acid	lb	NA	NA	0 – 230,000
Sodium hydroxide	lb	8,800 – 14,400	7,000 – 10,700	4,200 – 7,500

[a] Peak electricity demand during any hour would be as follows: conversion to U_3O_8, about 1.5 MW; conversion to UO_2, from 3.2 to 4.0 MW; conversion to metal, from 3.3 to 6.0 MW.

[b] scf = standard cubic feet measured at 14.7 psia and 60°F.

[c] NA = not applicable.

Source: LLNL (1997).

22 to 31 acres (9 to 13 ha) for construction and from 14 to 20 acres (5.5 to 8 ha) for operations (Table F.29). Siting a conversion facility at a location that is already dedicated to similar use could result in fewer land-use impacts because immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land use.

Impacts to local traffic patterns outside potential UO_2 conversion plant sites could be greater than those expected under the conversion to U_3O_8 option due to the potential for increased traffic volume associated with greater construction workforce demands. However, such impacts would be temporary and would be expected to diminish during the operations phase. The protective

TABLE F.29 Land Requirements for the Conversion Options

Option	Land Requirement (acres)[a] Construction	Operation
Conversion to U_3O_8	20	13
Conversion UO_2	22 – 31	14 – 20
Conversion to metal	23 – 26	15 – 16

[a] NUREG-1140 (McGuire 1985) suggests that each conversion facility establish a protective action distance for emergency planning, which would incorporate an area of about 960 acres around each facility.

Source: LLNL (1997).

action distance described in Section F.3.9.1 would be applicable to an area of about 960 acres around the facility.

F.3.9.3 Conversion to Metal

Land-use impacts from the conversion to uranium metal option would be minimal. Land requirements (Table F.29) would be similar to those discussed for the conversion to UO_2 option, and impacts related to construction traffic outside the conversion plant sites would be negligible. The protective action distance would be applicable to an area of about 960 acres around the facility.

F.3.9.4 Cylinder Treatment Facility

Impacts to land use from the construction and operation of a cylinder treatment facility would be negligible and of a lesser magnitude than those generated under any of the conversion options. Although the cylinder treatment facility could be a stand-alone facility, it is likely to be integrated into a depleted UF_6 conversion facility. If the cylinder treatment facility were incorporated into a conversion facility, it would require less than 1 acre (0.4 ha) of land, regardless of the conversion option. Such a small areal requirement would account for much less than 1% of the land available for development at the representative sites. If construction of a cylinder treatment facility and conversion facility occurred simultaneously, the peak construction labor force of 230 for the cylinder treatment facility could slightly increase the magnitude (expected to be negligible) of off-site traffic impacts associated with the conversion facility construction.

As a stand-alone facility, the cylinder treatment facility would require 8.7 acres (3.5 ha) of land for construction and 4.5 acres (2 ha) for operations. The areal requirement would probably not be large enough to result in land-use impacts, particularly if the facility were sited at a location already dedicated to a similar industrial-type use.

F.3.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur if the conversion options considered in this PEIS were implemented include impacts to cultural resources and environmental justice, as well as impacts to the visual environment (e.g., aesthetics), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of the conversion facilities. These impacts, although considered, were not analyzed in detail for one or both of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites (e.g., impacts on cultural resources, threatened and endangered species, wetlands, and environmental justice). These impacts would be more appropriately addressed in the second-tier NEPA documentation when specific sites are considered.

- Consideration of these impacts would not contribute to differentiation among the alternatives and, therefore, would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

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APPENDIX G:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR LONG-TERM STORAGE AS UF_6 AND URANIUM OXIDE

CONTENTS (APPENDIX G)

CONTENTS (Cont.)

TABLES

TABLES (Cont.)

TABLES (Cont.)

NOTATION (APPENDIX G)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

ALARA	as low as reasonably achievable
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 μm or less
ROI	region of influence

Chemicals

CaF_2	calcium fluoride
CO	carbon monoxide
HC	hydrocarbons
HF	hydrogen fluoride
NO_x	nitrogen oxides
SO_x	sulfur oxides
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_2F_2	uranyl fluoride
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

cm	centimeter(s)
cm^3	cubic centimeter(s)
ft	foot (feet)
ft^2	square foot (feet)
g	gram(s)
gal	gallon(s)
gpm	gallon(s) per minute
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
µg	microgram(s)
m	meter(s)
m^3	cubic meter(s)
min	minute(s)
mrem	millirem(s)
MWh	megawatt hour(s)
MWyr	megawatt year(s)
rem	roentgen equivalent man
s	second(s)
scm	standard cubic meter(s)
yd^3	cubic yard(s)
yr	year(s)

APPENDIX G:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR LONG-TERM STORAGE AS UF_6 AND URANIUM OXIDE

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the long-term storage options for DOE-generated UF_6 cylinders and uranium oxide considered in the PEIS. The discussion provides background information for these options, as well as a summary of the estimated environmental impacts associated with each option.

Storage is defined as holding material for a temporary period, after which the material is either converted to another chemical form, used, disposed of, or stored elsewhere. Storage options would preserve access to the depleted uranium for use at a later date by storing it in a retrievable form in a facility designed for indefinite, low-maintenance operation.

Storage Options

Depleted uranium could be stored until use at a later date. Storage options are defined by the chemical form of the uranium and the type of storage facility. The following storage options are considered in the PEIS:

Storage as UF_6. Storage of UF_6 could take place in cylinders similar to those currently used. Storage facilities considered include yards, buildings, and an underground mine.

Storage as U_3O_8. Depleted uranium could be stored in drums as U_3O_8 following conversion. Storage facilities considered for U_3O_8 include buildings, belowground vaults, and an underground mine.

Storage as UO_2. Similar to options for U_3O_8, depleted uranium could be stored in drums as UO_2 in buildings, belowground vaults, and an underground mine.

The storage options in the PEIS are defined by the chemical form of the depleted uranium stored and the type of storage facility. Depleted uranium could be stored as UF_6, or, following chemical conversion, as triuranium octaoxide (U_3O_8) or uranium dioxide (UO_2). Storage as UF_6 would take place in cylinders similar to those currently used, whereas U_3O_8 or UO_2 would be stored in drums. Several different types of storage facilities are considered for each chemical form (summarized in Table G.1). For storage of UF_6 cylinders, the storage options considered include outdoor yards, aboveground buildings, and an underground mine. For storage of U_3O_8 and UO_2 in drums, the storage options include aboveground buildings, belowground vaults, and an underground mine. Each type of storage facility is described in Section G.3.

TABLE G.1 Summary of Depleted Uranium Chemical Forms and Storage Options Considered

	Storage Option Considered			
Chemical Form	Yards	Buildings	Vaults	Mines
UF_6	Yes	Yes	No	Yes
U_3O_8	No	Yes	Yes	Yes
UO_2	No	Yes	Yes	Yes

The choice of the chemical form of the depleted uranium for storage would depend in part on the desired end use or disposition of the material. For instance, storage in the form of UF_6 would provide maximum flexibility for future uses; however, UF_6 is not as chemically stable as other chemical forms because it becomes a gas at relatively low temperatures and is soluble in water. Storage in the form of UO_2 or U_3O_8 is attractive in view of their long-term stability, and may be the form of the material preferred for use as shielding or for disposal.

All storage facilities would be stand-alone, single-purpose facilities consisting of a central receiving building/warehouse surrounded by storage areas, all within a security fence. The storage facility would be capable of receiving containers of depleted uranium by truck or railcar, inspecting the containers, repackaging the material if necessary, and placing the containers into storage. Depending on the option, containers would be stored in a series of yards, buildings, vaults, or underground mine tunnels (called drifts). Once placed in storage, the containers of depleted uranium would require only routine monitoring and maintenance activities. The containers would be routinely inspected for damage or corrosion, the air would be monitored for indications of releases that would signify the presence of damaged containers, and any damaged containers would be repaired or replaced. The storage facilities would be designed to protect the stored material from the environment and prevent potential releases of material to the environment.

In general, potential environmental impacts would occur during (1) construction of a storage facility, (2) routine storage facility operations, and (3) potential storage accidents. The potential impacts during construction are generally limited to the duration of the construction period and result from typical land-clearing and construction activities. Potential impacts during operations would result primarily from the handling and inspection of containers. Impacts could also occur from potential accidents that release hazardous materials to the environment.

In general, the environmental impacts from the storage options were evaluated on the basis of information described in the engineering analysis report (Lawrence Livermore National Laboratory [LLNL] 1997). For each storage option except storage as UF_6 in yards, the engineering analysis report provides preconceptual facility design data, including descriptions of facility layouts, resource requirements, estimates of effluents, wastes, and emissions, and estimates of potential accident scenarios. The design of facilities required for UF_6 storage in yards was partially based on current yard storage practices (Parks 1997), as well as the designs for building and mine storage of UF_6 presented in the engineering analysis report (LLNL 1997). The assessment considers storage of depleted uranium through the year 2039. Storage facilities were assumed to receive containers of DOE-generated depleted uranium over a 20-year period beginning in 2009 and store the material for a period of 11 years after receipt of the last container.

G.1 SUMMARY OF STORAGE OPTION IMPACTS

Potential environmental impacts for the storage options are summarized in Table G.2. The potential environmental impacts from the storage options are not site-specific because the location of a storage facility will not be decided until sometime in the future (see Chapter 3). Instead, for assessment purposes, the environmental impacts were determined for a storage facility at representative sites. A more detailed assessment of specific storage technologies and site conditions will be conducted as appropriate as part of the second tier of the *National Environmental Policy Act* (NEPA) process.

The following general conclusions can be drawn from the summary table:

- The environmental impacts from storage tend to be small for all chemical forms and types of storage facilities.

- For storage as UF_6, yard storage has slightly greater environmental impacts than storage in buildings or a mine.

- For storage as U_3O_8, the environmental impacts tend to be similar among buildings, vaults, and a mine.

- For storage as UO_2, the environmental impacts tend to be similar among buildings, vaults, and a mine.

- The differences in impacts among chemical forms are partially related to differences in material bulk densities, with denser material, such as UO_2, requiring less storage space. UF_6 storage impacts also consider the greater reactivity of this form and the small potential for release of HF gas. However, differences in environmental impacts among the forms tend to be small.

TABLE G.2 Summary of Long-Term Storage Option Impacts

A. UF_6

Impacts from Storage as UF_6 in Yards	Impacts from Storage as UF_6 in Buildings	Impacts from Storage as UF_6 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 680 person-rem	**Involved Workers:** Total collective dose: 240 person-rem	**Involved Workers:** Total collective dose: 240 person-rem
Total number of LCFs: 0.3 LCF	Total number of LCFs: 0.1 LCF	Total number of LCFs: 0.1 LCF
Noninvolved Workers: Negligible impacts	**Noninvolved Workers:** Negligible impacts	**Noninvolved Workers:** Negligible impacts
General Public: Negligible impacts	**General Public:** Negligible impacts	**General Public:** Negligible impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem
Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}	Risk of LCF to MEI: 8×10^{-6}
Collective dose: 7.5 person-rem	Collective dose: 7.5 person-rem	Collective dose: 7.5 person-rem
Number of LCFs: 3×10^{-3}	Number of LCFs: 3×10^{-3}	Number of LCFs: 3×10^{-3}
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.015 rem
Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}	Risk of LCF to MEI: 7×10^{-6}
Collective dose to population within 50 miles: 56 person-rem	Collective dose to population within 50 miles: 56 person-rem	Collective dose to population within 50 miles: 56 person-rem
Number of LCFs in population within 50 miles: 3×10^{-2} LCF	Number of LCFs in population within 50 miles: 3×10^{-2} LCF	Number of LCFs in population within 50 miles: 3×10^{-2} LCF

TABLE G.2 (Cont.)

Impacts from Storage as UF_6 in Yards	Impacts from Storage as UF_6 in Buildings	Impacts from Storage as UF_6 in a Mine
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 520 persons	Number of persons with potential for adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 520 persons	Number of persons potential for adverse effects (bounding accident frequency: 1 in 100 years to 1 in 10,000 years): 520 persons
Number of persons with potential for irreversible adverse effects: 440 persons	Number of persons with potential for irreversible adverse effects: 440 persons	Number of persons with potential for irreversible adverse effects: 440 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 2,500 persons	Number of persons with potential for adverse effects: 2,500 persons	Number of persons with potential for adverse effects: 2,500 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.1) fatality, approximately 92 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.25) fatality, approximately 150 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.36) fatality, approximately 187 injuries
	Air Quality	
Construction: 24-hour PM_{10} concentration potentially as large as 20% of standard; concentrations of other criteria pollutants all below 2% of respective standards	**Construction:** Annual NO_x concentration potentially as large as 3% of standard; concentrations of other criteria pollutants 1% or less of respective standards	**Construction:** All pollutant concentrations less than those for storage in buildings
Operations: Concentrations of all criteria pollutants below 0.03% of respective standards	**Operations:** Annual NO_x concentration potentially as large as 0.5% of standard; all other criteria pollutant concentrations 0.2% or less of respective standards	**Operations:** All pollutant concentrations less than those for storage in buildings

TABLE G.2 (Cont.)

Impacts from Storage as UF_6 in Yards	Impacts from Storage as UF_6 in Buildings	Impacts from Storage as UF_6 in a Mine
	Water	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
	Soil	
Construction: Moderate, but temporary, impacts	**Construction:** Moderate, but temporary, impacts	**Construction:** Moderate, but temporary, impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Construction: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Potentially moderate impacts on employment and income
Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Potentially moderate impacts on employment and income
	Ecology	
Loss of 77-144 acres; potentially moderate to large impacts to vegetation and wildlife	Loss of 62-131 acres; potentially moderate to large impacts to vegetation and wildlife	Loss of 32-96 acres; potentially moderate to large impacts to vegetation and wildlife
	Waste Management	
Construction: Negligible to moderate, but temporary, impacts (solid waste)	**Construction:** Negligible to moderate, but temporary, impacts (solid waste)	**Construction:** Negligible to moderate, but temporary, impacts (solid waste)
Operations: Negligible impacts (all waste forms)	**Operations:** Negligible impacts (all waste forms)	**Operations:** Negligible impacts (all waste forms)
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected
	Land Use	
Use of approximately 144 acres; potential moderate impacts	Use of approximately 131 acres; potential moderate impacts	Use of approximately 96 acres; potential moderate impacts, including impacts from disposal of excavated material

TABLE G.2 (Cont.)

B. U_3O_8

Impacts from Storage as U_3O_8 in Buildings	Impacts from Storage as U_3O_8 in Vaults	Impacts from Storage as U_3O_8 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 940 person-rem	**Involved Workers:** Total collective dose: 940 person-rem	**Involved Workers:** Total collective dose: 950 person-rem
Total number of LCFs: 0.4 LCF	Total number of LCFs: 0.4 LCF	Total number of LCFs: 0.4 LCF
Noninvolved Workers: Negligible impacts	**Noninvolved Workers:** Negligible impacts	**Noninvolved Workers:** Negligible impacts
General Public: Negligible impacts	**General Public:** Negligible impacts	**General Public:** Negligible impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 7.4 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 7.4 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 7.4 rem
Risk of LCF to MEI: 3×10^{-3}	Risk of LCF to MEI: 3×10^{-3}	Risk of LCF to MEI: 3×10^{-3}
Collective dose: 670 person-rem	Collective dose: 670 person-rem	Collective dose: 670 person-rem
Number of LCFs: 0.3	Number of LCFs: 0.3	Number of LCFs: 0.3
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.22 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.22 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.22 rem
Risk of LCF to MEI: 1×10^{-4}	Risk of LCF to MEI: 1×10^{-4}	Risk of LCF to MEI: 1×10^{-4}
Collective dose to population within 50 miles: 16 person-rem	Collective dose to population within 50 miles: 16 person-rem	Collective dose to population within 50 miles: 16 person-rem
Number of LCFs in population within 50 miles: 8×10^{-3} LCF	Number of LCFs in population within 50 miles: 8×10^{-3} LCF	Number of LCFs in population within 50 miles: 8×10^{-3} LCF

TABLE G.2 (Cont.)

Impacts from Storage as U_3O_8 in Buildings	Impacts from Storage as U_3O_8 in Vaults	Impacts from Storage as U_3O_8 in a Mine
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 1 person	Number of persons with potential for adverse effects: 1 person	Number of persons with potential for adverse effects: 1 person
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.29) fatality, approximately 165 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.26) fatality, approximately 151 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.43) fatality, approximately 222 injuries
	Air Quality	
Construction: Annual NO_x concentration potentially as large as 2.2% of standard; all other criteria pollutant concentrations less than 0.7% of respective standards	**Construction:** Annual NO_x concentration potentially as large as 13% of standard; all other criteria pollutant concentrations less than 3% of respective standards	**Construction:** All pollutant concentrations less than those for storage in buildings
Operations: Annual NO_x concentration potentially as large as 0.6% of standard; all other criteria pollutant concentrations less than 0.2% of respective standards	**Operations:** Annual NO_x concentration potentially as large as 1% of standard; all other criteria pollutant concentrations less than 0.3% of respective standards	**Operations:** All pollutant concentrations less than those for storage in buildings

TABLE G.2 (Cont.)

Impacts from Storage as U_3O_8 in Buildings	Impacts from Storage as U_3O_8 in Vaults	Impacts from Storage as U_3O_8 in a Mine
	Water	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
	Soil	
Construction: Moderate, but temporary, impacts	**Construction:** Moderate, but temporary, impacts	**Construction:** Moderate, but temporary, impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Construction: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Potentially moderate impacts on employment and income
Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Potentially moderate impacts on employment and income
	Ecology	
Loss of 72-148 acres; potentially moderate to large impacts to vegetation and wildlife	Loss of 86-212 acres; potentially moderate to large impacts to vegetation and wildlife	Loss of 54-124 acres; potentially moderate to large impacts to vegetation and wildlife
	Waste Management	
Construction: Minimal to moderate, but temporary, impacts (solid waste)	**Construction:** Minimal to moderate, but temporary, impacts (solid waste)	**Construction:** Minimal to moderate, but temporary, impacts (solid waste)
Operations: Negligible impacts (all waste forms)	**Operations:** Negligible impacts (all waste forms)	**Operations:** Negligible impacts (all waste forms)
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected
	Land Use	
Use of approximately 148 acres; potential moderate impacts	Use of approximately 213 acres; potential large impacts, including impacts from disposal of excavated material	Use of approximately 120 acres; potential moderate impacts, including impacts from disposal of excavated material

TABLE G.2 (Cont.)

C. UO_2

Impacts from Storage as UO_2 in Buildings	Impacts from Storage as UO_2 in Vaults	Impacts from Storage as UO_2 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 540 person-rem	**Involved Workers:** Total collective dose: 540 person-rem	**Involved Workers:** Total collective dose: 540 person-rem
Total number of LCFs: 0.2 LCF	Total number of LCFs: 0.2 LCF	Total number of LCFs: 0.2 LCF
Noninvolved Workers: Negligible impacts	**Noninvolved Workers:** Negligible impacts	**Noninvolved Workers:** Negligible impacts
General Public: Negligible impacts	**General Public:** Negligible impacts	**General Public:** Negligible impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	Bounding accident frequency: 1 in 10,000 years to 1 in 1 million years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 7.7 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 7.7 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 7.7 rem
Risk of LCF to MEI: 3×10^{-3}	Risk of LCF to MEI: 3×10^{-3}	Risk of LCF to MEI: 3×10^{-3}
Collective dose: 700 person-rem	Collective dose: 700 person-rem	Collective dose: 700 person-rem
Number of LCFs: 0.3	Number of LCFs: 0.3	Number of LCFs: 0.3
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem
Risk of LCF to MEI: 1×10^{-4}	Risk of LCF to MEI: 1×10^{-4}	Risk of LCF to MEI: 1×10^{-4}
Collective dose to population within 50 miles: 17 person-rem	Collective dose to population within 50 miles: 17 person-rem	Collective dose to population within 50 miles: 17 person-rem
Number of LCFs in population within 50 miles: 9×10^{-3} LCF	Number of LCFs in population within 50 miles: 9×10^{-3} LCF	Number of LCFs in population within 50 miles: 9×10^{-3} LCF

TABLE G.2 (Cont.)

Impacts from Storage as UO_2 in Buildings	Impacts from Storage as UO_2 in Vaults	Impacts from Storage as UO_2 in a Mine
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 1 person	Number of persons with potential for adverse effects: 1 person	Number of persons with potential for adverse effects: 1 person
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.16) fatality, approximately 111 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.14) fatality, approximately 104 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.24) fatality, approximately 143 injuries
	Air Quality	
Construction: Annual NO_x concentration potentially as large as 2% of standard; all other criteria pollutant concentrations 0.5% or less of respective standards	**Construction:** Annual NO_x concentration potentially as large as 11% of standard; all other criteria pollutant concentrations 3% or less of respective standards	**Construction:** All pollutant concentrations less than those for storage in buildings
Operations: Annual NO_x concentration potentially as large as 0.4% of standard; all other criteria pollutant concentrations 0.1% or less of respective standards	**Operations:** Annual NO_x concentration potentially as large as 0.8% of standard; all other criteria pollutant concentrations 0.2% or less of respective standards	**Operations:** All pollutant concentration less than those for storage in buildings
	Water	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater

TABLE G.2 (Cont.)

Impacts from Storage as UO_2 in Buildings	Impacts from Storage as UO_2 in Vaults	Impacts from Storage as UO_2 in a Mine
	Soil	
Construction: Moderate, but temporary, impacts	**Construction:** Moderate, but temporary, impacts	**Construction:** Moderate, but temporary, impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Construction: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Construction:** Potentially moderate impacts on employment and income
Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public finances	**Operations:** Potentially moderate impacts on employment and income
	Ecology	
Potentially moderate impacts to vegetation and wildlife	Potentially large impacts to vegetation and wildlife	Potentially moderate impacts to vegetation and wildlife
	Waste Management	
Construction: Minimal to moderate, but temporary, impacts (solid waste)	**Construction:** Minimal to moderate, but temporary, impacts (solid waste)	**Construction:** Minimal to moderate, but temporary, impacts (solid waste)
Operations: Negligible impacts (all waste forms)	**Operations:** Negligible impacts (all waste forms)	**Operations:** Negligible impacts (all waste forms)
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected
	Land Use	
Use of approximately 79 acres; potential moderate impacts	Use of approximately 114 acres; potential moderate impacts	Use of approximately 74 acres; potential moderate impacts, including impacts from disposal of excavated material

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; NO_x = nitrogen oxides; PM_{10} = particulate matter with a mean diameter of 10 μm or less; ROI = region of influence.

G.2 DESCRIPTION OF OPTIONS

This section provides a brief summary of the different storage options considered in the assessment of storage impacts. The information is based on preconceptual design data provided in the engineering analysis report (LLNL 1997). That report includes detailed information, such as descriptions of facility layouts, resource requirements, estimates of effluents, wastes, and emissions, and descriptions of potential accident scenarios.

The chemical form of the depleted uranium (i.e., whether it is UF_6, U_3O_8, or UO_2) determines the type of storage container, the total number of containers required, and the storage configuration (the way containers would be stacked). For storage of UF_6, U_3O_8, and UO_2, the following assumptions would apply to all storage facilities:

- The analysis of storage impacts for UF_6 was based on the assumption that UF_6 would be stored in cylinders meeting all applicable storage requirements, either the current cylinders or new cylinders. Cylinder preparation for transportation to a long-term storage site would require thorough inspection of the cylinders to determine that they meet transportation requirements; cylinders not meeting these requirements would be placed in overcontainers for shipment or would have their contents transferred to new cylinders. Cylinder preparation activities were assumed to be carried out so that the cylinders could be delivered to the long-term storage site and placed into storage without further preparation. However, a certain number of cylinders were assumed to be damaged during transport and handling, and the contents of these cylinders were assumed to be transferred to new cylinders at the long-term storage site.

- Depleted UF_6 cylinders would be stacked two high, as is the current practice for outside storage of these cylinders, in rows 1.2 m (4 ft) apart.

- U_3O_8 would be stored in powdered form in 55-gal (210-L) drums, consistent with current practice. Based on a bulk density of about 3 g/cm^3, the weight of a filled drum would be about 700 kg (1,600 lb). Approximately 714,000 55-gal drums would be required. The drums would be stored in rows of four-drum pallets, two pallets high. The width of each row would be about 1.2 m (4 ft), with 1 m (3 ft) between rows to allow for drum inspections.

- UO_2 would be stored in a sintered form in 30-gal (110-L) drums. Based on a bulk density of sintered UO_2 of about 9 g/cm^3, a filled 30-gal drum weighs about 1,100 kg (2,400 lb). Approximately 420,000 30-gal drums would be required. As with U_3O_8, the drums would be stored in rows of four-drum pallets, two pallets high. The width of each row would be about 1 m (3 ft), with 1 m (3 ft) between rows, to allow for drum inspections.

- For UF_6 cylinders and U_3O_8 and UO_2 drums, the contents of containers damaged during handling and storage would be transferred to new containers (0.7% of the drums containers received annually were assumed to require replacement [LLNL 1997]).

In these configurations, the total area required for storage would range from 96 to 144 acres (39 to 58 ha) for UF_6, from 124 to 212 acres (50 to 86 ha) for U_3O_8, and from 74 to 114 acres (30 to 46 ha) for UO_2. The storage areas differ primarily because the bulk densities differ between the chemical forms. Although the total storage area required differs among chemical forms, the basic designs of the storage facilities — buildings, vaults, and mines — would be similar for each. For instance, buildings of similar type would be used for the storage of UF_6, U_3O_8, and UO_2; however, 17 buildings would be required for storage of UF_6 cylinders, 20 buildings for storage of U_3O_8 drums, and only 9 buildings for storage of UO_2 drums. Because UF_6 is currently stored in cylinder yards at the three storage sites, long-term storage of UF_6 in cylinder yards at a single, centralized location was also examined.

The following sections provide a summary description of each of the storage options. Note that in addition to the primary storage units, each facility also would have an administration building, a receiving warehouse, a repackaging building (attached to the receiving warehouse), and a workshop. Storage facilities for UF_6 would require a cylinder washing facility to recover the heels from damaged cylinders after the removal of the UF_6.

G.2.1 Storage in Yards

Only depleted UF_6 would be stored in outdoor yards. Yard construction would be similar to current practice; the yards would consist of an 8-in. (20-cm) stabilized base under a 12-in. (30-cm) nonreinforced concrete pad. Twenty pads with dimensions of approximately 160 m × 80 m would be required. Additional facilities required for yard storage include a receiving warehouse and repackaging building, a cylinder washing building, and an administration building. Maintenance activities assessed for long-term yard storage are similar to those associated with the continued storage strategy (Parks 1997), and include routine inspections, ultrasonic inspections, valve monitoring and maintenance, and regular painting of the cylinders. The contents of any of the cylinders damaged during handling or storage would be subsequently transferred to new cylinders; the old cylinders would be washed and sent for further disposition.

G.2.2 Storage in Buildings

Storage in buildings is considered for UF_6, U_3O_8, and UO_2. Aboveground buildings would be built on-grade and consist of a concrete slab covered by a steel, preengineered, single-span structure. This type of building is commonly called a "Butler" building. Each building would be approximately 840 ft (260 m) long and 160 ft (50 m) wide, with a height of approximately 20 ft

(6 m). The number of buildings required for storage of UF_6, U_3O_8, and UO_2 would be 17, 20, and 9, respectively. Construction would follow generally accepted practices. Additional facilities are provided which combine receiving/inspection operations with administration, shipping/unloading capabilities, and permanent monitoring capabilities (to ensure the integrity of the stored containers).

G.2.3 Storage in Vaults

Storage in vaults is considered for U_3O_8 and UO_2. Belowground vaults are subsurface reinforced concrete structures, 131 ft (40 m) wide × 266 ft (81 m) long, with a height of approximately 20 ft (6 m). The concrete walls are 1 ft (0.3 m) thick, with a floor slab thickness of 2 ft (0.6 m). The majority of the structure is located underground, with only the roof area above grade. A steel roof supported by trusses is used which can be removed to allow access to the vault by a mobile crane outside the structure. A total of 79 vaults would be required for storage of U_3O_8, and 35 for storage of UO_2.

G.2.4 Storage in a Mine

Storage in a mine is considered for UF_6 (dry mine only), U_3O_8, and UO_2. A belowground mine facility consists of surface buildings where the depleted uranium is inspected and prepared for storage, access shafts from the surface to the belowground drifts, and mined storage drifts. Storage drifts are lateral extensions of belowground tunnels in which depleted uranium can be stored. The dimensions of the drifts are 35 ft (11 m) wide × 330 ft (100 m) long and 18 ft (5 m) high. Each drift would contain two rows of UF_6 cylinders stored side-by-side, five rows of 30-gal UO_2 drums on pallets, or four rows of 55-gal U_3O_8 drums on pallets. The number of drifts required for storage of UF_6, U_3O_8, and UO_2 would be 180, 215, and 105, respectively.

G.2.5 Storage Technologies and Chemical Forms Considered But Not Analyzed

Storage of UF_6 in the potentially moist environment of a belowground vault or a mine was not considered due to potential accelerated corrosion of the steel cylinders. In addition, storage as depleted uranium metal was not considered because uranium metal is not as stable as U_3O_8 or UO_2, it is subject to surface oxidation.

G.3 IMPACTS OF OPTIONS

This section provides a summary of the potential environmental impacts associated with the storage options, including impacts from construction and facility operations. Information related to the assessment methodologies for each area of impact is provided in Appendix C.

The environmental impacts from the storage options were evaluated based primarily on the information described in the engineering analysis report (LLNL 1997). The following general assumptions apply to storage facility operations:

- The assessment considers storage of depleted uranium through the year 2039.
- Two phases of facility operations are considered. Phase I beginning in 2009 corresponds to the first 20 years, when the facilities would receive UF_6 cylinders or UO_2 or U_3O_8 drums from off-site and place them into storage. Phase II corresponds to the next 11 years, when passive storage of cylinders or drums would take place.
- Construction of support buildings and initial storage facilities would begin about 2007, and additional storage facilities would be built as needed throughout Phase I.
- All storage containers would be routinely inspected, and any damaged containers would be replaced.
- UF_6 cylinder content transfers and empty cylinder washing activities would be the only sources of emissions associated with normal (nonaccident) operations. All U_3O_8 and UO_2 drum content transfers would be enclosed mechanical operations that would not involve material releases.

As described in Chapter 3, the potential environmental impacts from the storage options were not determined on a site-specific basis because the location of a storage facility would not be decided until sometime in the future. Instead, for yards, buildings, and vaults, the environmental impacts were calculated using the site conditions at the three current depleted UF_6 storage sites. These three representative sites were used to provide a reasonable range of environmental conditions. For assessment of mine storage, a representative dry location was assumed (storage in a wet mine environment was not considered reasonable due to potential corrosion of containers). A more detailed assessment of site considerations would be addressed, as appropriate, as part of the second phase (tier) of the programmatic NEPA approach.

G.3.1 Human Health — Normal Operations

G.3.1.1 Radiological Impacts

Radiation doses and the associated cancer risks were estimated for exposed individuals and collective populations. Radiation doses to the involved workers would result mainly from external radiation during handling of containers of uranium and during routine inspection activities. Radiation doses to noninvolved workers and the general public would result from release of uranium compounds to the environment. According to the engineering analysis report (LLNL 1997), airborne emissions of depleted uranium would be negligible during normal operations of the storage facilities. Results from water quality analyses (Section G.3.4) also showed that potential impacts to surface water would be negligible. Therefore, radiological impacts to noninvolved workers and the off-site general public would be negligible for all storage options.

Discussion of the methodologies used in radiological impact analysis is provided in Appendix C and Cheng et al. (1997). The estimated results for involved workers are presented in Table G.3 and G.4 for all storage options. The results indicate that average radiation exposure to involved workers would be less than 1,200 mrem/yr.

G.3.1.1.1 Storage as UF_6

Radiation exposures for involved workers from storage as UF_6 would result mainly from cylinder handling, painting (for storage in yards), repackaging, and surveillance activities. Collective radiological impacts from storage in yards would be more than twice that from storage in buildings and mines. Compared with buildings and mines, storage in yards would require more cylinder inspection and cylinder maintenance (painting) activities to control corrosion in an outdoor environment. Radiological impacts would be similar for storage in buildings and storage in a mine. The collective dose would range from about 7.6 to 22 person-rem/yr (considering Phase I and Phase II) for a worker population of 19 to 26 individuals. The corresponding number of latent cancer fatalities (LCFs) among the involved workers would range from 0.003 to 0.009 per year (1 to 3 LCFs over a 300-year period).

The average annual individual doses were obtained by dividing the collective dose by the number of workers. To provide a conservative estimate of doses, the calculations did not consider the implementation of as low as reasonably achievable (ALARA) practices to minimize exposures. Because the exact number of workers required to conduct all types of activities is uncertain at this preliminary stage, the estimated average individual doses also involve a large degree of uncertainty. The estimated average individual dose ranges from 290 to 920 mrem/yr for the storage options, with a corresponding individual risk of a latent cancer fatality of 0.0001 to 0.0004 per year (a chance of about 1 to 4 in 10,000 per year). The average individual dose would be well below the regulatory limit of 5,000 mrem/yr (10 *Code of Federal Regulations* [CFR] Part 835) and would be smaller than the DOE administrative control limit of 2,000 mrem/yr (DOE 1992).

G.3.1.1.2 Storage as U_3O_8

For storage as U_3O_8, the worker activities would be expected to be similar among the three storage options — buildings, vaults, and mines. Therefore, radiological impacts to involved workers would be similar among these options. For all three options, the estimated collective dose is about

TABLE G.3 Radiological Doses from Long-Term Storage Options under Normal Operations

	Dose to Receptor					
	Involved Worker[a]		Noninvolved Worker[b]		General Public[c]	
Option	Average Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)
Storage as UF_6						
Yards	920	22	~0	~0	~0	~0
Buildings	290	7.6	~0	~0	~0	~0
Mine	420	7.6	~0	~0	~0	~0
Storage as U_3O_8						
Buildings	880	30	~0	~0	~0	~0
Vaults	910	30	~0	~0	~0	~0
Mine	1,200	30	~0	~0	~0	~0
Storage as UO_2						
Buildings	810	17	~0	~0	~0	~0
Vaults	670	17	~0	~0	~0	~0
Mine	920	17	~0	~0	~0	~0

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual dose and collective dose for the worker population. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[b] Noninvolved workers are individuals who do not participate in material handling activities and individuals who work on-site but not within the facility. Because negligible airborne emission of radioactive materials would be expected from the storage facility (LLNL 1997), radiation doses to noninvolved workers would be negligible.

[c] The off-site general public is defined as residents who live within a radius of 50 miles (80 km) around the storage site. Radiation doses to the off-site public would be negligible because airborne emission of radioactive materials (LLNL 1997) and impacts to surface water quality would be negligible (Section G.3.4).

TABLE G.4 Latent Cancer Risks from Long-Term Storage Options under Normal Operations

Option	Latent Cancer Risk to Receptor: Involved Worker[a] Average Risk (risk/yr)	Involved Worker[a] Collective Risk (fatalities/yr)	Noninvolved Workers[b] MEI Risk (risk/yr)	Noninvolved Workers[b] Collective Risk (fatalities/yr)	General Public[c] MEI Risk (risk/yr)	General Public[c] Collective Risk (fatalities/yr)
Storage as UF_6						
Yards	4×10^{-4}	9×10^{-3}	~0	~0	~0	~0
Buildings	1×10^{-4}	3×10^{-3}	~0	~0	~0	~0
Mine	2×10^{-4}	3×10^{-3}	~0	~0	~0	~0
Storage as U_3O_8						
Buildings	4×10^{-4}	1×10^{-2}	~0	~0	~0	~0
Vaults	4×10^{-4}	1×10^{-2}	~0	~0	~0	~0
Mine	5×10^{-4}	1×10^{-2}	~0	~0	~0	~0
Storage as UO_2						
Buildings	3×10^{-4}	7×10^{-3}	~0	~0	~0	~0
Vaults	3×10^{-4}	7×10^{-3}	~0	~0	~0	~0
Mine	4×10^{-4}	7×10^{-3}	~0	~0	~0	~0

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual risk and collective risk for the worker population.

[b] Noninvolved workers are individuals who do not participate in material handling activities and individuals who work on-site but not within the facility. Because negligible airborne emission of radioactive materials would be expected from the storage facility (LLNL 1997), cancer risks to noninvolved workers would be negligible.

[c] The off-site general public is defined as residents who live within a radius of 50 miles (80 km) around the storage site. Cancer risks to the off-site public would be negligible because airborne emission of radioactive materials (LLNL 1997) and impacts to surface water quality would be negligible (Section G.3.4).

30 person-rem/yr for 25 to 34 workers. The corresponding number of LCFs among workers would be about 0.01 per year (about 1 LCF over a 100-year period).

The estimated average individual dose ranges from about 880 to 1,200 mrem/yr for the U_3O_8 storage options, with a corresponding individual risk of a latent cancer fatality of 0.0004 to 0.0005 per year (a chance of about 1 in 2,000). The average dose would be well below the regulatory dose limit of 5,000 mrem/yr.

Storage as U_3O_8 would result in greater collective exposures for involved workers than storage as UF_6 or UO_2 because a larger number of containers would be needed for U_3O_8 than for UF_6 and UO_2. Consequently, the number of operations for transferring containers, retrieving damaged containers, and surveying the stored inventory would be the greatest for U_3O_8 among the three chemical forms for depleted uranium.

G.3.1.1.3 Storage as UO_2

The storage practices for UO_2 drums would be similar to those for U_3O_8 drums; however, the total number of UO_2 drums would be less than the number of U_3O_8 drums. As a result, the estimated collective exposures to involved workers from drum handling and inspection activities would be less for UO_2 than for U_3O_8. On the other hand, the number of UO_2 drums would be greater than the number of UF_6 cylinders. Therefore, collective exposures for storage in buildings and in a mine would be greater for UO_2 than for UF_6.

Radiological impacts to workers would be similar among the UO_2 storage options. The collective dose to involved workers would be about 17 person-rem/yr for 19 to 26 workers. The corresponding number of latent cancer fatalities among workers would be about 0.007 per year (about 1 LCF over a 140-year period).

The estimated average individual dose ranges from 800 to 920 mrem/yr, with a corresponding individual risk of an LCF of about 0.0003 to 0.0004 per year (a chance of about 1 in 2,500). The average dose would be well below the regulatory dose limit.

G.3.1.2 Chemical Impacts

Chemical impacts to the maximally exposed individual (MEI) were assessed for noninvolved workers and the public. However, according to the engineering analysis report (LLNL 1997), no airborne emissions of uranium would be expected for long-term storage facilities and only small quantities of hydrogen fluoride (HF) would be emitted under the UF_6 storage option. Therefore, the only potential chemical exposures for noninvolved workers and the public that were considered are those that would result from airborne emissions of HF emitted from the cylinder transfer and washing operations. In addition, potential chemical exposures resulting from the storage facilities wastewater emissions were considered for the off-site general public; however, results from water quality analyses (Section G.3.4.1) showed that potential impacts to surface water bodies would be negligible. Information on the methodologies used for the chemical impact analysis is provided in Appendix C and Cheng et al. (1997).

The results of the analysis of hazardous chemical human health impacts from long-term storage options are summarized in Table G.5. No impacts on human health from chemical exposures would be expected during normal operations of storage facilities.

For the long-term storage option, the engineering analysis report (LLNL 1997) assumed that a low percentage of cylinders and drums would require repackaging annually due to handling or

TABLE G.5 Chemical Impacts to Human Health for Long-Term Storage Options under Normal Operations[a]

		Impacts to Receptor			
		Noninvolved Workers[a]		General Public[b]	
Option	Type	Hazard Index for MEI[c]	Collective Risk[d] (ind. at risk/yr)	Hazard Index for MEI[c]	Collective Risk[d] (ind. at risk/yr)
Storage as UF_6	Yards	~ 0	–	~ 0	–
	Buildings	~ 0	–	~ 0	–
	Mines	~ 0	–	~ 0	–
Storage as U_3O_8	Buildings	~ 0	–	~ 0	–
	Vaults	~ 0	–	~ 0	–
	Mines	~ 0	–	~ 0	–
Storage as UO_2	Buildings	~ 0	–	~ 0	–
	Vaults	~ 0	–	~ 0	–
	Mines	~ 0	–	~ 0	–

[a] Noninvolved workers include individuals who work at the facility but are not involved in hands-on activities and individuals who work on-site but not within the facility. Because no airborne emission of uranium and/or very low levels of HF are expected from the storage facility, there would essentially be no noncarcinogenic health impacts to the noninvolved workers.

[b] The off-site general public is defined as residents who live with a radius of 50 miles (80 km) around the storage site. There would essentially be no noncarcinogenic health impacts to the general public because no airborne emission of uranium and/or very low levels of HF are expected from the storage facility, there would essentially be no noncarcinogenic health impacts to the noninvolved workers.

[c] The hazard index is an indicator for potential health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

[d] Calculation of population risk is not applicable when the corresponding hazard index for the MEI is less than 1.

corrosion damage. These repackaging operations would result in the only potential releases and exposures to uranium and fluoride compounds for the storage options. For drum repackaging, electrically powered transfer equipment would pour the contents of the damaged drums into new drums, minimizing involved worker contact with the drum contents. The transfer equipment would operate in such a way as to keep the operation enclosed and eliminate dust generation for the U_3O_8 and UO_2 storage forms.

For storage as UF_6, repackaging would require heating the cylinder in an autoclave and transferring the contents to a new cylinder. A small "heel" of UF_6 (approximately 22 lb [10 kg]) would remain in the emptied cylinder; this material would be removed in the cylinder washing building, converted to uranyl fluoride (UO_2F_2) and calcium fluoride (CaF_2), and disposed of. Small amounts of HF would be released from the cylinder washing building stack from the conversion of the UF_6 heels to UO_2F_2. The maximum annual emission of HF for the Phase I and Phase II operational periods of long-term UF_6 storage would be about 0.10 kg/yr (in yards). In comparison, the maximum estimated annual emission of HF for any of the depleted UF_6 conversion options would be 408 kg/yr. Therefore, the maximum estimated annual emission of HF from any of the UF_6 storage facilities would be more than 4,000 times lower than the maximum annual emission of HF from conversion facilities. Because the results of the conversion analyses (Appendix F) did not indicate any human health impacts and the atmospheric release and transport of HF would occur under similar conditions, the small quantities of HF present in the storage facility emissions would also not result in human health impacts.

For storage as UF_6, it should also be noted that emissions due to breaches were not assumed because all cylinders would be inspected once every 4 years and would be repackaged immediately if any handling or corrosion damage was identified. Additionally, yard storage assumes that rigorous maintenance would take place, such as ultrasonic test inspections, valve monitoring, and regular painting.

Airborne emissions of depleted uranium are not expected during normal operations of the storage facilities, according to data provided in the engineering analysis report (LLNL 1997). Therefore, no matter which chemical form of depleted uranium is selected, chemical impacts to noninvolved workers and the off-site general public would be negligible.

G.3.2 Human Health — Accident Conditions

For long-term storage as U_3O_8 and UO_2, a range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents was presented in the engineering analysis report (LLNL 1997). Accidents analyzed for long-term storage in yards were consistent with those analyzed for continued cylinder storage (Appendix D), as given in the safety analysis reports (LMES 1997a-c). These accidents are listed in Table G.6. The following sections present the results for radiological and chemical health impacts of the highest consequence

TABLE G.6 Accidents Considered for the Long-Term Storage Options

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Storage as UF_6					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Storage as U_3O_8					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/ billet inside the repackaging building	A single U_3O_8 drum is damaged by a forklift and spills its contents onto the ground inside the repackaging building.	U_3O_8	0.00028	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The repackaging building is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	U_3O_8	33	30	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the repackaging building structure and its confinement systems.	U_3O_8	33	0.5	Ground

TABLE G.6 (Cont.)

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Storage as U_3O_8 (Cont.)					
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire or explosion inside the repackaging building	A fire or explosion within the repackaging facility affects the contents of a single pallet of drums.	U_3O_8	0.0011	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Storage as UO_2					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/ billet inside the repackaging building	A single UO_2 drum is damaged by a forklift and spills its contents onto the ground inside the repackaging building.	UO_2	0.00011	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The repackaging building is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	UO_2	33	30	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the repackaging building structure and its confinement systems.	UO_2	33	0.5	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire or explosion inside the repackaging building	A fire or explosion within the repackaging facility affects the contents of a single pallet of drums.	UO_2	0.00045	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA

[a] Ground-level releases were assumed to occur outdoors on concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

accident in each frequency category. Results for all accidents listed in Table G.6 are presented in Policastro et al. (1997). Detailed descriptions of the methodology and assumptions used in these calculations are also provided in Appendix C and Policastro et al. (1997).

G.3.2.1 Radiological Impacts

The radiological doses to various receptors for the accidents that would result in the highest dose from each frequency category are listed in Table G.7. The LCF risks for these accidents are given in Table G.8. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions and three representative sites were considered for each long-term storage option (see Appendix C). The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely category have a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

- The maximum radiological dose to noninvolved worker and general public MEIs (assuming an accident occurred) would be 7.7 rem. This dose is less than the 25 rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the U.S. Nuclear Regulatory Commission (NRC 1994).

- The overall radiological risk to noninvolved worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table G.8] by the annual probability of occurrence by the number of years of operations) would be less than 1 for all accidents.

G.3.2.2 Chemical Impacts

The accidents considered in this section are listed in Table G.6. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables G.9 and G.10. The results are presented as (1) number of people with potential for adverse effects and (2) number of people with potential for irreversible adverse effects. The tables present the results for the accident within the frequency category that would affect the largest number of people (total of noninvolved workers and off-site population) (Policastro et al. 1997). The numbers of noninvolved workers and

TABLE G.7 Estimated Radiological Doses per Accident Occurrence for the Long-Term Storage Options

Option/Accident[a]	Frequency Category[b]	Maximum Dose[c]: Noninvolved Workers: MEI (rem)	Maximum Dose[c]: Noninvolved Workers: Population (person-rem)	Maximum Dose[c]: General Public: MEI (rem)	Maximum Dose[c]: General Public: Population (person-rem)	Minimum Dose[c]: Noninvolved Workers: MEI (rem)	Minimum Dose[c]: Noninvolved Workers: Population (person-rem)	Minimum Dose[c]: General Public: MEI (rem)	Minimum Dose[c]: General Public: Population (person-rem)
Storage as UF_6									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	7.1	2.3×10^{-3}	3.0×10^{-1}	3.3×10^{-3}	8.1×10^{-2}	7.8×10^{-5}	7.4×10^{-3}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	7.5	1.5×10^{-2}	5.6×10^{1}	3.7×10^{-3}	5.2×10^{-1}	1.9×10^{-3}	5.2×10^{-1}
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	2.5	4.9×10^{-3}	2.7×10^{-1}	8.7×10^{-4}	2.2×10^{-1}	6.2×10^{-4}	2.5×10^{-2}
Storage as U_3O_8									
Mishandling/drop of drum inside the repackaging building	L	9.4×10^{-9}	3.0×10^{-6}	9.7×10^{-9}	1.8×10^{-6}	2.8×10^{-12}	8.1×10^{-25}	4.8×10^{-10}	5.2×10^{-8}
Earthquake	U	7.4	6.7×10^{2}	2.2×10^{-1}	1.6×10^{1}	3.1×10^{-1}	7.8	7.4×10^{-3}	6.4×10^{-1}
Fire or explosion inside the repackaging building	EU	3.6×10^{-8}	1.2×10^{-5}	3.7×10^{-8}	6.7×10^{-6}	1.1×10^{-11}	3.1×10^{-24}	1.8×10^{-9}	2.0×10^{-7}
Storage as UO_2									
Mishandle/drop of drum inside the repackaging building	L	3.7×10^{-9}	1.2×10^{-6}	3.8×10^{-9}	7.0×10^{-7}	1.1×10^{-12}	3.2×10^{-25}	1.9×10^{-10}	2.1×10^{-8}
Earthquake	U	7.7	7.0×10^{2}	2.3×10^{-1}	1.7×10^{1}	3.2×10^{-1}	8.1	7.7×10^{-3}	6.7×10^{-1}
Fire or explosion inside the repackaging building	EU	1.5×10^{-8}	4.8×10^{-6}	1.5×10^{-8}	2.8×10^{-6}	4.4×10^{-12}	1.3×10^{-24}	7.5×10^{-10}	8.3×10^{-8}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[c] Maximum and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

TABLE G.8 Estimated Radiological Health Risks per Accident Occurrence for the Long-Term Storage Options[a]

		Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI	Population	MEI	Population	MEI	Population	MEI	Population
Storage as UF_6									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	3×10^{-3}	1×10^{-6}	2×10^{-4}	1×10^{-6}	3×10^{-5}	4×10^{-8}	4×10^{-6}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	3×10^{-3}	7×10^{-6}	3×10^{-2}	1×10^{-6}	2×10^{-4}	1×10^{-6}	3×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	1×10^{-3}	2×10^{-6}	1×10^{-4}	3×10^{-7}	9×10^{-5}	3×10^{-7}	1×10^{-5}
Storage as U_3O_8									
Mishandle/drop of drum inside the repackaging building	L	4×10^{-12}	1×10^{-9}	5×10^{-12}	9×10^{-10}	1×10^{-15}	3×10^{-28}	2×10^{-13}	3×10^{-11}
Earthquake	EU	3×10^{-3}	3×10^{-1}	1×10^{-4}	8×10^{-3}	1×10^{-4}	3×10^{-3}	4×10^{-6}	3×10^{-4}
Fire or explosion inside the repackaging building	I	1×10^{-11}	5×10^{-9}	2×10^{-11}	3×10^{-9}	4×10^{-15}	1×10^{-27}	9×10^{-13}	1×10^{-10}
Storage as UO_2									
Mishandle/drop of drum inside the repackaging building	L	1×10^{-12}	5×10^{-10}	2×10^{-12}	3×10^{-10}	4×10^{-16}	1×10^{-28}	9×10^{-14}	1×10^{-11}
Earthquake	EU	3×10^{-3}	3×10^{-1}	1×10^{-4}	9×10^{-3}	1×10^{-4}	3×10^{-3}	4×10^{-6}	3×10^{-4}
Fire or explosion inside the repackaging building	I	6×10^{-12}	2×10^{-9}	8×10^{-12}	1×10^{-9}	2×10^{-15}	5×10^{-28}	4×10^{-13}	4×10^{-11}

a Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCFs) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

b The bounding accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

c Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

d Maximum and minimum risks reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

TABLE G.9 Number of Persons with Potential for Adverse Effects from Accidents under the Long-Term Storage Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Storage as UF_6									
Yard									
Corroded cylinder spill, dry conditions	L	Yes	240	No	0	Yes	2	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	520	Yes	10	Yes[f]	52	No	0
Vehicle-induced fire, three full 48G cylinders	EU	Yes	310	Yes	2,500	Yes[f]	0	Yes	3
Small plane crash, 48G cylinders	I	Yes	290	Yes	53	Yes[f]	0	No	0
Buildings/Mine									
Corroded cylinder spill, dry conditions	L	Yes	240	No	0	Yes	2	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	520	Yes	10	Yes[f]	52	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	310	Yes	2,500	Yes[f]	0	Yes	3
Small plane crash, 2 full 48G cylinders	I	Yes	290	Yes	53	Yes[f]	0	No	0
Storage as U_3O_8									
Mishandle/drop of drum/ cylinder inside[g]	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes	1	No	0	No	0	No	0
Fire or explosion involving reagent inside[g]	EU	No	0	No	0	No	0	No	0
Storage as UO_2									
Mishandle/drop of drum/ cylinder inside[g]	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes	1	No	0	No	0	No	0
Fire or explosion involving reagent inside[g]	EU	No	0	No	0	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 31 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential adverse effects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the worker and general public population distributions for the representative sites were used, which did not show receptors at the MEI locations.

[g] These accidents would result in the largest plume sizes, although no people would be affected.

TABLE G.10 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under the Long-Term Storage Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Storage as UF_6									
Yard									
Corroded cylinder spill, dry conditions	L	Yes	5	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	370	Yes[f]	0	Yes	3	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	440	Yes[f]	0	Yes	4	No	0
Small plane crash, 2 full 48G cylinders	I	Yes	2	No	0	No	0	No	0
Buildings/Mine									
Corroded cylinder spill, dry conditions	L	Yes	5	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	370	Yes[f]	0	Yes	3	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	440	Yes[f]	0	Yes	4	No	0
Small plane crash, 2 full 48G cylinders	I	Yes	2	No	0	No	0	No	0
Storage as U_3O_8									
Mishandle/drop of drum/cylinder inside[g]	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes[f]	0	No	0	No	0	No	0
Fire or explosion involving reagent inside[g]	EU	No	0	No	0	No	0	No	0
Storage as UO_2									
Mishandle/drop of drum/cylinder inside[g]	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes[f]	0	No	0	No	0	No	0
Fire or explosion involving reagent inside[g]	EU	No	0	No	0	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential irreversible adverse effects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the worker and general public population distributions for the representative sites were used, which did not show receptors at the MEI locations.

[g] These accidents would result in the largest plume sizes, although no people would be affected.

members of the off-site public represent the impacts if the associated accident was assumed to occur. The accidents listed in Tables G.9 and G.10 are not identical because an accident with the largest impacts for the adverse effects endpoint might not lead to the largest impacts for the irreversible adverse effects endpoint. The results of the chemical impacts analysis may be summarized as follows:

- If the accidents identified in Tables G.9 and G.10 did occur, the number of persons in the off-site population with potential for adverse effects would range from 0 to 2,500 (maximum corresponding to vehicle-induced fire accident involving three full 48G cylinders), and the number of off-site persons with potential for irreversible adverse effects was estimated to be 0.

- If the accidents identified in Tables G.9 and G.10 did occur, the number of noninvolved workers with potential for adverse effects would range from 0 to 520 (maximum corresponding to the corroded cylinder spill accident with rain conditions), and the number of noninvolved workers with potential for irreversible adverse effects would range from 0 to 440 (maximum corresponding to corroded cylinder spill accident with pooling).

- The noninvolved worker population would receive the majority of the severe impacts and the off-site population much less, except for the vehicle-induced fire accident involving three full 48G cylinders. In such case, the plume would rise and hit the ground at distances downwind. The overall risk (frequency times consequence), however, is very low due to the low frequency of occurrence.

- The impacts resulting from the vehicle-induced fire involving three full 48G UF_6 cylinders would be large for members of the general public in terms of potential adverse effects because of the considerable source terms associated with such an accident.

- The overall impact for accidents associated with long-term storage as UF_6 in buildings/mines would be about the same as that associated with storage in a yard. Storage as U_3O_8 would have almost the same impacts as storage as UO_2, with both options having very small impacts compared with the potential impacts for storage as UF_6.

- Stack releases would have much lower impacts than ground-level releases.

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years in operations (31 years, 2009 through 2039). The results indicated that the maximum risk values would be less than 1 for all accidents except the following:

- *Potential Adverse Effects:*

  Corroded cylinder spill, dry conditions (L, likely): Workers
  Corroded cylinder spill, wet conditions – rain (U, unlikely): Workers

- *Potential Irreversible Adverse Effects:*

  Corroded cylinder spill, dry conditions (L, likely): Workers
  Corroded cylinder spill, wet conditions – rain (U, unlikely): Workers

These risk values are conservative because the numbers of people affected were based on assuming (1) meteorological conditions that would result in the maximum reasonably foreseeable plume size (i.e., F stability and 1 m/s wind speed) and (2) wind in the direction that would lead to maximum numbers of individuals exposed for noninvolved workers or for the general population.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible adverse effects was estimated. All the bounding case accidents shown in Table G.10 would involve releases of UF_6 and potential exposure to HF and uranium compounds. These exposures would likely be high enough to result in death for 1% or less of the persons experiencing irreversible adverse effects (Policastro et al. 1997). This would mean that for noninvolved workers experiencing a range of 0 to 440 irreversible adverse effects, 0 to about 4 deaths would be expected. No deaths would be expected among the general public. These are the maximum potential consequences of the accidents, the upper ends of the ranges assume worst-case weather conditions and that the wind would be blowing in the direction where the highest numbers of people would be exposed.

G.3.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries to all long-term storage facility workers is calculated using industry-specific statistics from the Bureau of Labor Statistics, as reported by the National Safety Council (1995). Construction and manufacturing annual fatality and injury rates were used respectively for the duration of the construction and operational phases of the facility.

No on-the-job fatalities are predicted for any of the storage options analyzed (range of 0.10 for UF_6 yard storage to 0.43 for U_3O_8 mine storage, for the total construction, Phase I operations, and Phase II operations). The range of predicted injuries is about 92 to 222 for the entire facility lifetimes. Physical hazard risks of fatality and injury are presented in Table G.11 by construction, Phase I, and Phase II components. The largest component of physical hazard risks generally results

TABLE G.11 Potential Impacts to Human Health from Physical Hazards under Accident Conditions for the Long-Term Storage Options

	Impacts to All Long-Term Storage Facility Workers[a]					
	Incidence of Fatalities[b]			Incidence of Injuries[b]		
Option	Construction	Phase I Operations	Phase II Operations	Construction	Phase I Operations	Phase II Operations
Storage as UF_6	0.04 – 0.30	0.04	0.02	16 – 110	48 – 53	24 – 29
Storage as U_3O_8	0.20 – 0.36	0.04 – 0.05	0.02	83 – 132	55 – 64	25 – 27
Storage as UO_2	0.09 – 0.18	0.04	0.02	33 – 66	50 – 53	22 – 24

[a] Impacts are reported as ranges, which result from variations in the employment requirements for the different long-term storage chemical forms and facility types. All construction and operational workers at the storage facilities are included in physical hazard risk calculations.

[b] Fatality and injury incidence rates used in the calculations were taken from National Safety Council (1995).

from construction; except for UF_6 yard storage, construction physical hazard risks are 3 to 4 times greater than risks from Phase I and II operations combined. The maximum impacts are predicted for storage as U_3O_8 in mines; the differences in predicted impacts result from the increased work effort required to construct mines and to inspect the greater number of U_3O_8 containers during the operational phases. However, the overall differences in ranges of physical hazard risks between chemical forms and storage types are fairly small.

For storage as UF_6, the probability of an on-the-job fatality ranges from 0.10 for storage in yards to 0.36 for storage in mines — including construction, Phase I, and Phase II of storage. The predicted injury incidence ranges from about 92 to 187 injuries over the lifetime of the facility.

For storage as U_3O_8, the probability of an on-the-job fatality ranges from 0.29 for storage in vaults to 0.43 for storage in mines — including construction, Phase I, and Phase II of storage. The predicted injury incidence ranges from about 151 to 222 injuries over the lifetime of the facility.

For storage as UO_2, the probability of an on-the-job fatality ranges from 0.16 for storage in buildings to 0.24 for storage in mines — including construction, Phase I, and Phase II of storage. The predicted injury incidence ranges from about 104 to 143 injuries over the lifetime of the facility.

G.3.3 Air Quality

The methodology used to analyze impacts of the long-term storage options is described in Appendix C and Tschanz (1997). The storage site was assumed to be centered within a larger facility, and pollutant concentrations — carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides

(NO_x), sulfur oxides (SO_x), and PM_{10} (particulate matter with a mean diameter of 10 μm or less) — were estimated for the boundaries of that facility. Screening modeling of construction emissions was used to estimate hourly pollutant concentrations under very conservative meteorological conditions at the boundary point that would be the shortest distance from the center of the facility. The maximum 1-hour concentrations for the representative facilities examined are shown in Table G.12. These impacts would occur when construction was under way at the corner of the storage site nearest the chosen boundary point. Concentrations from construction at the center of the storage site would be 1.5 to 2 times smaller than the ones listed in the table. Among the listed results, the PM_{10} values might require close consideration in actual construction of any sites similar to the assumed preconceptual ones. Based on the size of the estimated 1-hour concentrations, it is possible that, under particularly unfavorable conditions, concentrations could exceed the 24-hour PM_{10} standard of 150 μg/m^3.

Air quality impacts associated with storage in a mine were not analyzed in detail because the potential emissions associated with mine storage would be smaller than those for the other storage options considered. For example, during construction of facilities for long-term storage of U_3O_8, CO emissions for mine construction would be about 30% of those for aboveground buildings and only about 10% of those for belowground vaults. Similar ratios would apply for comparisons of emissions during operations associated with placing the uranium compounds in the storage facilities.

The maximum impacts of CO and NO_x at the facility boundaries during operations to place depleted uranium in storage are shown in Table G.13 for the averaging periods for which standards

TABLE G.12 Maximum 1-Hour Pollutant Concentrations at Long-Term Storage Facility Boundaries as a Result of Construction Emissions under Worst-Case Meteorological Conditions

	Maximum 1-Hour Concentration (μg/m^3)				
	Aboveground Building Storage			Belowground Vault Storage	
Pollutant	UF_6	U_3O_8	UO_2	U_3O_8	UO_2
CO	77	94	54	280	140
HC	34	38	21	110	55
NO_x	390	450	250	1,300	670
SO_x	26	30	17	85	44
PM_{10}[a]	370	420	240	460	250

[a] Fugitive dust emissions from land disturbance have been included with PM_{10} emissions from construction equipment to estimate total PM_{10} concentrations.

TABLE G.13 Maximum Pollutant Concentrations at Facility Boundaries from Operations Emissions during Long-Term Storage

	CO				NO_x	
	1-Hour Average		8-Hour Average		Annual Average	
Option	Pollutant Concentration ($\mu g/m^3$)	Percent of Standard at Maximum	Pollutant Concentration ($\mu g/m^3$)	Percent of Standard at Maximum	Pollutant Concentration ($\mu g/m^3$)	Percent of Standard at Maximum
Aboveground Buildings						
Storage as UF_6	6.2 – 7.9	0.02	1.6 – 1.9	0.02	0.18 – 0.48	0.5
Storage as U_3O_8	6.8 – 7.5	0.02	1.8 – 2.3	0.02	0.24 – 0.57	0.6
Storage as UO_2	5.4 – 6.9	0.02	1.1 – 1.7	0.02	0.13 – 0.39	0.4
Belowground Vaults						
Storage as U_3O_8	9.3 – 12.9	0.03	2.6 – 3.2	0.03	0.40 – 0.95	1.0
Storage as UO_2	10.0 – 10.7	0.03	2.1 – 3.1	0.03	0.27 – 0.82	0.8

exist. In all cases, the concentrations due to the storage operations are 1% or less of the standards. Although not shown, the comparisons between SO_x concentrations and the corresponding standards are similar to those for CO.

The results of comparing the impacts from CO and NO_x emissions for simultaneously conducted construction and operations activities are shown in Table G.14. The maximum construction impacts would result when construction took place at the corner of the storage site nearest the facility boundary point closest to the facility center. The operations emissions were assumed to be distributed uniformly over the entire storage site. Although the annual construction emissions are comparable to the corresponding operations emissions for both buildings and vaults, the construction impacts shown are considerably larger. Basically, this is the effect of concentrating the construction emissions in a small area closer to the boundary receptor point than is the average distance for the operations emissions. During most years, the construction would be farther from the boundary and have less impact. Even for the results shown in Table G.14, the combined construction and operations impacts are less than the applicable air quality standards.

The emissions from routine monitoring and maintenance following completion of the storage operations in all cases would be less than 25% as large as the operations emissions. Thus, in all cases, the maintenance air quality impacts would be less than 25% of the operations impacts alone.

Some of the estimated criteria pollutant impacts during the operations phase of long-term storage of UF_6 in yards, when both construction and operations would occur simultaneously, are shown in Table G.15. Construction would be the dominant contributor to most of the impacts, accounting for between 85% of the total for CO to nearly 100% for PM_{10}. The combined impacts

TABLE G.14 Maximum Air Quality Impacts from Construction Emissions for Long-Term Aboveground Building and Belowground Vault Storage of U_3O_8 Compared with Impacts from Operations Emissions

Pollutant/ Storage Option	Averaging Period	Maximum Concentration from Construction Emissions ($\mu g/m^3$)	Operations Concentration as Percent of Construction Concentration
CO			
Building	1-hour average	49	15
	8-hour average	8.1	22
Vault	1-hour average	170	8
	8-hour average	37	7
NO_x			
Building	Annual average	2.2	21
Vault	Annual average	12.4	7

TABLE G.15 Maximum Pollutant Concentrations at Facility Boundaries during Operations for the Long-Term Storage of Depleted UF_6 in Yards

		Pollutant Concentration ($\mu g/m^3$)		
Pollutant	Averaging Time	Construction	Operations	Maximum of Construction and Operations as Percent of Standard
CO	1 hour	8.2 –36	3.1 – 6.2	0.1
	8 hours	1.4 – 5.1	1.0 – 1.2	0.06
NO_x	Annual	0.14 – 1.4	0.014 – 0.026	1.4
PM_{10}	24 hours	7.5 – 31	0.012 – 0.013	21
	Annual	0.42 – 4.1	0.0014 – 0.0026	8

of construction and operations would be below the relevant standards, although closer examination of the likely PM_{10} impacts might be required if this option were to be implemented.

In the maintenance phase of UF_6 storage in yards, the impacts would be similar to those of operations without construction. The maintenance impacts for CO, NO_x, and PM_{10} would be 0.71, 0.76, and 0.77, respectively, of those listed for operations in Table G.15.

Only small quantities of HF would be released from the process stack, averaging 0.06 kg/yr during the operations phase and 0.012 kg/yr during the maintenance phase. The estimated maximum average annual HF concentration is about 3×10^{-6} $\mu g/m^3$.

No quantitative estimate was made of the impacts on the criterion pollutant ozone. Ozone formation is a regional issue that would be affected by emissions data for the entire area around a proposed long-term storage site. The pollutants most related to ozone formation that would result from the long-term storage of depleted UF_6 are HC and NO_x. In later Phase II studies, when specific technologies and sites would be selected, the potential effects on ozone of these pollutants at a proposed site could be put in perspective by comparing them with the total emissions of HC and NO_x in the surrounding area. Small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region.

G.3.4 Water and Soil

The methodology used to determine water and soil impacts is presented in Appendix C and Tomasko (1997).

G.3.4.1 Surface Water

To evaluate construction impacts, it was conservatively assumed that construction would be completed in 1 year. Essentially negligible impacts to surface water would be expected for all long-term storage options.

G.3.4.1.1 Buildings

The total land requirements for aboveground storage in buildings would be greatest for storing depleted uranium as U_3O_8 (148 acres [60 ha]) (Table G.16). Of this area, about 70 acres (29 ha) would be disturbed, and 6 acres (2.4 ha) would be paved. This alteration of soil would impact surface waters by increasing the amount of runoff. On a sitewide scale, however, this amount of increased impermeable land would have a negligible impact on nearby rivers (0.1 to 0.4% of the and representative site areas available for runoff). In addition, there would be no measurable impacts to the existing floodplains.

TABLE G.16 Summary of Environmental Parameters for Long-Term Storage in Buildings

Option	Unit	Requirements		
		Storage as UF_6	Storage as U_3O_8	Storage as UO_2
Total land area	acres	131	148	79
Total disturbed land	acres	62	72	35
Total paved area	acres	5	6	4
Construction water	million gal/yr	0.5	0.6	0.3
Excavation	yd^3	157,000	183,000	81,000
Water	million gal/yr			
Phase I		1.2	1.4	1.1
Phase II		1.0	1.0	0.9
Wastewater	million gal/yr			
Construction		0.05	0.06	0.03
Phase I		1.1	1.2	1.1
Phase II		0.9	0.9	0.8

Water would be needed for constructing the storage buildings. As indicated in Table G.16, the total quantity of water ranges from about 0.3 million gal/yr (0.6 gpm) for the UO_2 storage option to about 0.6 million gal/yr (1.1 gpm) for storing depleted uranium as U_3O_8. If this water were obtained from a nearby river, the impact would be negligible (less than 0.00005% of the average flow).

During construction, wastewater would be discharged to nearby surface waters. About 0.05 million gal/yr (0.1 gpm) of water would be discharged for the U_3O_8 option (see Table G.16). The primary contaminants of concern would be construction chemicals, organics, and some suspended solids. By following good engineering practices (e.g., stockpiling materials away from surface water drainages, covering construction piles with tarps, and cleaning small chemical spills as soon as they occurred), concentrations in the wastewater would be expected to be very small and well within any regulatory standards. In addition, once in the nearby surface water, dilution would occur in excess of 20 million:1 for average flows. Because the levels of contamination from construction would be very low, impacts to sediment would also be negligible.

During Phase I, annual water use would range from 1.1 to 1.4 million gal/yr for the three storage forms (UF_6, UO_2, and U_3O_8) (Table G.16). For a constant rate of use, the maximum withdrawal from nearby surface water would be about 55 gpm. This amount of withdrawal corresponds to less than 0.0001% of the average river flows. The impact of this increase in withdrawal on the flow system (particularly floodplains) would be negligible.

Impacts to surface water quality could also occur during Phase I and II. These impacts would result from releasing water containing chemicals or radionuclides. The maximum wastewater release of 1.2 million gal/yr (2.3 gpm) would occur during Phase I (Table G.16). This wastewater would contain low concentrations of pollutants that would be within National Pollutant Discharge Elimination System (NPDES) guidelines. Additional large dilution would occur in the receiving water.

Impacts to surface waters during Phase II would be even less than the impacts produced by Phase I operations because of smaller volumes of raw water used and wastewater released (Table G.16). Impacts to surface water would, therefore, be negligible.

None of the accident scenarios presented in LLNL (1997) would produce impacts to surface water. Accidents occurring within the concrete-bottomed buildings would be contained and isolated from surface water, and accidents in which the building fails would primarily produce potential impacts via the air pathway.

G.3.4.1.2 Vaults

The total land requirements for vault storage would be roughly similar to the requirements for building storage (Table G.17). The amount of increased impermeable land would have a negligible impact on nearby rivers. In addition, there would be no measurable impacts to floodplains.

The quantity of water needed for construction would be similar to that for constructing buildings (Table G.17). If this water were obtained from a nearby river, the impact would be negligible for any of the storage forms (less than 0.00001% of the average flows). During construction, wastewater volumes similar to the building option would be discharged to surface waters (U_3O_8 option; see Table G.17), and the impacts to surface waters would also be negligible.

During Phase I and Phase II operations, annual water use would be about two times greater than for the building option (Table G.17). The impact of this withdrawal on the flow system (particularly floodplains) would be negligible, as would the impacts to surface water.

None of the accident scenarios presented in LLNL (1997) would produce impacts to surface water. If an accident occurred within the vault it would be contained and isolated from surface water.

TABLE G.17 Summary of Environmental Parameters for Long-Term Storage in Vaults

		Physical Needs	
Option	Unit	Storage as U_3O_8	Storage as UO_2
Total land area	acres	212	114
Total disturbed area	acres	86	40
Total paved area	acres	21	10
Excavation	million yd^3	1.7	0.75
Water			
Phase I	million gal/yr	1.1	1.2
Phase II	million gal/yr	0.8	0.9
Wastewater			
Construction	million gal/yr	0.8	0.4
Phase I	million gal/yr	1.1	1.0
Phase II	million gal/yr	0.9	0.8
Construction water	million gal/yr	0.8	0.4

G.3.4.1.3 Mine

Requirements for long-term storage in a mine are listed in Table G.18. These parameters are all similar to those for vault storage, and all potential impacts would be similar.

G.3.4.1.4 Yards

For long-term storage of depleted uranium as UF_6 in yards, 144 acres (58 ha) of land would be disturbed and 13 acres (5.3 ha) would be paved. This alteration of soil would impact local surface waters by increasing the amount of runoff. The amount of increased runoff, however, would be negligible on a sitewide scale because the land area affected would range from 0.25 to 1.5% of the representative site land areas available. In addition there would be no measurable impacts to the existing floodplains.

Water would be needed for constructing the long-term storage yards. Approximately 6.4 million gal/yr of water would be required. This amount of withdrawal would represent less than 0.000033% of average flows. The impact of this increase in withdrawal on the flow system (particularly floodplains) would be negligible.

TABLE G.18 Summary of Environmental Parameters for Long-Term Storage in a Mine

		Physical Needs		
Option	Unit	Storage as UF_6	Storage as U_3O_8	Storage as UO_2
Total land area	acres	96	124	74
Total disturbed area	acres	32	54	25
Total paved area	acres	3	3	3
Excavation	million yd^3	1.8	2.2	1.2
Water				
Phase I	million gal/yr	1.2	1.3	1.2
Phase II	million gal/yr	0.9	1.0	0.9
Wastewater				
Construction	million gal/yr	0.1	0.1	0.07
Phase I	million gal/yr	1.1	1.3	1.1
Phase II	million gal/yr	0.9	0.9	0.8
Underground area	acres	114	138	77
Construction water	million gal/yr	1.1	1.3	0.7

During construction of the storage yard, surface water quality could be impacted. The primary contaminants of concern would be chemicals used in construction, organic compounds, and some suspended solids. By following good engineering practices, concentrations in the wastewater would be expected to be very small and less than applicable U.S. Environmental Protection Agency (EPA) guidelines. Once the construction water mixed with surface water, dilution would occur. Depending on the volumetric release of water during construction, dilution would be about 1 million:1.

During normal operations, there would be no emissions that would impact surface water because all cylinders are assumed to be new at the start of the storage option, they would be inspected once every 4 years, and they would be replaced if any handling damage occurred. In addition, no impacts to surface water would result from accidents because no accidents are identified in LLNL (1997) that would produce emissions that would interact directly or indirectly with surface water.

G.3.4.2 Groundwater

The only groundwater impacts for long-term storage in buildings, vaults, or mines would occur during construction. Phase I and Phase II operations would produce no impacts because groundwater would not be used as a source for operations and there would be no direct discharges of wastewater to the aquifers. For vault construction, drains would be provided on the upgradient side of the facility to prevent groundwater from entering the facility and mobilizing any spilled contaminants. Accident sequences described in LLNL (1997) would also have no impacts on groundwater because the building, vault, or mine would isolate contaminants and eliminate any direct pathways to the underlying aquifers.

At any site, groundwater quality could be impacted by construction. For example, chemicals stored on the ground could be mobilized by precipitation and infiltrate to the underlying aquifers. By adopting good engineering and construction practices (e.g., covering material to prevent interaction with rain, promptly cleaning any chemical spills, and providing retention basins to catch and hold contaminated runoff), groundwater concentrations would be kept below EPA (1996) guidelines. Overall, impacts from construction would, therefore, be negligible. Phase I and Phase II operations would have no impacts because groundwater would not be used as a source for operations and there would be no direct discharges of wastewater to the aquifers.

The only groundwater impacts for long-term storage in yards would occur during construction. These impacts would primarily be to groundwater quality; impacts to the depth of groundwater, recharge, and flow direction would not be measurable on a sitewide scale because of the limited size of the facility. Impacts could, however, affect quality. For example, chemicals stored on the ground could be mobilized by precipitation and infiltrate to the underlying aquifers. By adopting good engineering and construction practices, impacts to quality would be minimized, and groundwater concentrations would be kept below EPA (1996) guidelines.

As with surface water, there would be no emissions that would impact groundwater during normal operations because all cylinders were assumed to be in good condition at the start of the storage option, they would be inspected once every 4 years, and they would be replaced if any handling damage occurred. In addition, no accident scenarios identified in LLNL (1997) would lead to direct or indirect groundwater contamination.

G.3.4.3 Soil

G.3.4.3.1 Buildings

The only impacts to soil from long-term storage in buildings would occur during construction. The maximum impact would occur for construction of the U_3O_8 building (Table G.16). Up to 148 acres (60 ha) of land (4.4 to 29% of the representative site land areas available) would be disturbed, and 183,000 yd^3 (140,000 m^3) of soil would be excavated. These impacts would include modifications in the local topography, increased permeability and erosion potential in areas where the land surface is plowed, decreased permeability and erosion potential in areas where the soil is compacted by heavy equipment, and decreased soil quality in areas exposed to chemical alteration. On a sitewide scale, the impacts would be moderate; however, the impacts would be temporary. That is, with time the disturbed soil conditions would return to previous conditions everywhere except in paved lots. As discussed in Section G.3.4.1.1, this area would be about 6 acres (2.4 ha) (0.2 to 0.4% of the total land area available). On a sitewide scale, this impact would be negligible.

By following good engineering practices (e.g., disturbing as little soil as possible, contouring and reseeding disturbed land, scheduling activities to minimize land disturbance, controlling runoff, using tarps to prevent chemical/rainfall interaction, and cleaning any spills as soon as they occur), impacts to soils would be minimized.

G.3.4.3.2 Vaults

The only impacts to soil from long-term storage in vaults would occur during construction. The largest impact to soils would occur for construction of the U_3O_8 vault (Table G.16). Up to 212 acres (86 ha) of land (6 to 13% of the land area available) would be disturbed, and up to 1.7 million yd^3 (1.3 million m^3) of soil would be excavated. These impacts would include modifications in the local topography. If the excavated soil were spread evenly over the 212-acre (86-ha) facility, a mound 5 ft (1.5 m) deep would be created. This impact could be mitigated by trucking the soil off-site. Other impacts would include increased permeability and erosion potential in areas where the land surface is plowed or mounded, decreased permeability and erosion potential in areas where the soil is compacted by heavy equipment, and decreased soil quality in areas exposed to chemical alteration. On a sitewide scale, the impacts would be moderate; however, the impacts would, to a large extent, be temporary and readily mitigated. With time the disturbed soil conditions would be returned to existing conditions everywhere except in paved lots. As discussed in Section G.3.4.1.2, this area would be a maximum of 21 acres (8.5 ha) (0.6 to 1.2% of the total land area available). On a sitewide scale, this impact would be minor. By following good engineering practices, impacts to soils would be kept to a minimum.

G.3.4.3.3 Mine

The only impacts to soils from long-term storage in a mine would occur during construction. The maximum impact to soils would occur for construction of the U_3O_8 mine facility (Table G.16). Up to 124 acres (50 ha) of land (3.3 to 7.3% of the representative site land areas available) would be disturbed, and up to 2.4 million yd^3 (1.8 million m^3) of soil and rock would be excavated. These impacts would include modifications in topography (e.g., if the excavated material were spread evenly over the 124-acre (50-ha) facility, a mound 12 ft (3.7 m) high would be created; however, this impact could be mitigated by trucking the material off-site), increased permeability and erosion potential in areas where the land surface is plowed or mounded, decreased permeability and erosion potential in areas where the soil is compacted by heavy equipment, and decreased soil quality in areas exposed to chemical alteration. Impacts would be moderate; however, the impacts would, to a large extent, be temporary and readily mitigated. That is, with time, the disturbed soil would be returned to previous conditions everywhere except in paved lots. This area would be about 3 acres (1.2 ha) (0.1 to 0.4% of the total land area available) and would result in a minor impact to soils. By following good engineering practices, impacts to soils would be kept to a minimum.

G.3.4.3.4 Yards

About 144 acres (58 ha) of land would be disturbed by construction of the long-term storage yard facility (3.8 to 8.5% of the land area available. Of this area, 13 acres (5.3 ha) would be paved (0.4 to 0.8% of the land area available). In addition, about 250,000 yd^3 (192,000 m^3) of soil would be excavated. Impacts from construction would include modifications in topography, increased permeability and erosion potential in areas where the soil would be broken, decreased permeability and erosion potential in areas where the soil would be compacted by heavy equipment or paving, and decreased soil quality in areas subjected to chemical loading. On a sitewide basis, the impacts would be moderate, but they would be mostly temporary. That is, with time, soil conditions would return to previous conditions everywhere except beneath paved lots, the 20 UF_6 storage pads, and associated buildings. By following good engineering practices, impacts to soils would be kept to a minimum.

There would be no emissions that would impact soils during normal operations because all cylinders would be inspected once every 4 years, and they would be replaced if any handling damage occurred. In addition, there are no identified accident scenarios that would lead to direct or indirect contamination.

G.3.5 Socioeconomics

Calculations for the analysis of socioeconomic impacts were based on detailed cost data developed for trial storage facilities, including the impacts of facility construction, operation and maintenance, emplacement and closure, and surveillance and monitoring activities. Impacts for each facility are presented for the peak year of construction and the first year of operations.

The potential socioeconomic impacts of long-term storage in yards, buildings, and vaults were estimated using the three representative sites. Because the sites that would be chosen for long-term storage in mines are not known, the analysis estimated the impacts of these facilities for a generic site. The impacts of long-term storage at the representative sites on regional economic activity was estimated for a region of influence (ROI): these impacts are presented in detail in Section G.3.5.1. The impacts of long-term storage at a generic site are presented in Section G.3.5.2. The methodology for assessing socioeconomic impacts is discussed in Appendix C.

Long-term storage would probably have a small impact on socioeconomic conditions in the ROIs surrounding the three sites described in Chapter 3, Sections 3.1.8, 3.2.8, and 3.3.8. This is partly because a major proportion of expenditures associated with procurement for the construction and operation of each technology option would flow outside of the ROI to other locations in the United States, reducing the concentration of local economic effects of the long-term storage yard.

Slight changes in employment and income would occur in each ROI as a result of local spending of personal consumption expenditures derived from employee wages and salaries, local procurement of goods and services required to construct and operate a long-term storage facility, and other local investment associated with construction and operation. In addition to creating new (direct) jobs at each site, the facility would also create indirect employment and income in the ROI as a result of jobs and procurement expenditures at each site. Jobs and income created directly by a long-term storage facility, together with indirect activity in the ROI, would contribute slightly to reduction in unemployment in the ROI surrounding each site. Minimal impacts are expected on local population growth and, consequently, on local housing markets and local fiscal conditions.

The effects of constructing and operating long-term storage facilities were assessed with regard to regional economic activity (measured in terms of employment and personal income) and population, housing, and local public revenues and expenditures. The results are presented as ranges to include impacts that would occur for a storage facility at each of the representative sites. Impacts for the three sites are presented for the peak year of construction and during the first year of operations. Table G.19 presents the potential range of impacts for long-term storage at the three representative sites.

G.3.5.1 Long-Term Storage as UF_6

During the peak year of construction of a UF_6 long-term storage yard or building, 100 to 200 direct jobs would be created at the site, and 80 to 310 additional jobs would be indirectly created in the ROI surrounding a representative site (Table G.19) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, between 180 and 510 jobs would be created. Construction activity would also produce direct and indirect income in the ROI, with total income of $7 million to $15 million produced during the peak year. In the first year of operations of the facility, between 80 and 100 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI surrounding each site, with total income of $4 million in the first year. Construction and operation of a UF_6 storage facility would result in an increase in the projected baseline compound annual average growth rate in employment in the representative site ROI of 0.001 to 0.006 percentage points from 2006 through 2039.

Construction of a UF_6 storage facility would be expected to generate direct in-migration of 130 to 280 in the peak year of construction. Additional indirect job in-migration would be expected into the site ROIs, bringing the total number of in-migrants to between 170 and 430 in the

TABLE G.19 Potential Socioeconomic Impacts of the Long-Term Storage Options for Yards, Buildings, and Vaults

Parameter	Long-Term Storage as UF_6		Long-Term Storage as UO_2		Long-Term Storage as U_3O_8	
	Construction[a]	Operations[b]	Construction[a]	Operations[b]	Construction[a]	Operations[b]
Economic activity in the ROI						
Direct jobs	100 – 200	50	120 – 140	70	170 – 210	60
Indirect jobs	80 – 310	30 – 50	100 – 190	30 – 60	140 – 280	40 – 70
Total jobs	180 – 510	80 – 100	220 –330	100 – 130	310 – 490	100 – 130
Income ($ million)						
Direct income	5 – 9	3	5 – 6	3	8 – 9	3 – 4
Total income	7 – 15	4	7 – 10	4	11 – 15	5 – 8
Population in-migration into the ROI	170 – 430	50 – 70	210 – 280	70 – 100	300 – 420	80 – 100
Housing demand						
Number of units in the ROI	60 – 160	20 – 30	80 – 100	30 – 40	110 – 150	30 – 40
Public finances						
Change in ROI fiscal balance (%)	<0.1 – 0.3	<0.01	0.1 – 0.2	<0.1 – 0.1	0.1 – 0.3	<0.1 – 0.1

[a] Impacts are for peak year of construction, either 2007 or 2008. Socioeconomic impacts from construction were assessed for 2007 through 2028.

[b] Impacts are the annual averages for the emplacement period (2009–2028). Annual averages for the surveillance and maintenance period (2029–2039) were estimated to be equal to or less than these values.

peak year (Table G.19). Operation of the facility would be expected to generate direct job in-migration of 40 in the first year. Additional indirect job in-migration into the ROI would also be expected, bringing the total number of in-migrants to between 50 and 70 in the first year of operations. Construction and operation of a UF_6 storage facility would result in an increase in the projected baseline compound annual average growth rate in representative site ROI populations of 0.001 to 0.01 percentage points from 2006 through 2039.

A UF_6 storage facility would generate a demand for 60 to 160 additional rental housing units during the peak year of construction (Table G.19), representing an impact of 3.5 to 8% on the projected number of vacant rental housing units at the representative sites. A demand for 20 to 30 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.2 to 0.5% on the number of vacant owner-occupied housing units at each site.

During the peak year of construction, between 170 and 430 persons would in-migrate into the ROI at each site, leading to an increase of less than 0.1 to 0.3% over ROI-forecasted baseline revenues and expenditures at the representative sites (Table G.19). In the first year of operations, 50 to 60 in-migrants would be expected, leading to an increase of less than 0.01% in local revenues and expenditures at the three sites.

G.3.5.2 Long-Term Storage as UO_2

During the peak year of construction of a UO_2 long-term storage building or vault, 120 to 140 direct jobs would be created at the site and 100 to 190 additional jobs indirectly in the ROI surrounding each site (Table G.19) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, between 220 and 330 jobs would be created. Construction activity would also produce direct and indirect income in the ROI, with total income of $7 million to $10 million produced during the peak year. In the first year of operations of the facility, between 100 and 130 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI surrounding the site, with total income of $4 million in the first year. Construction and operation of a UO_2 storage facility would result in an increase in the projected baseline compound annual average growth rate in employment in the ROI of 0.01 to 0.02 percentage points from 2006 to 2039.

Construction of a UO_2 storage facility would be expected to generate direct in-migration of 160 to 190 in the peak year of construction. Additional indirect job in-migration would be expected into the site ROIs, bringing the total number of in-migrants to between 210 and 280 in the peak year (Table G.19). Operation of the facility would be expected to generate direct job in-migration of between 11 and 70 in the first year. Additional indirect job in-migration into the ROI would also be expected, bringing the total number of in-migrants to between 70 and 100 in the first year of operations. Construction and operation of a UO_2 storage facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.01 percentage points from 2006 to 2039.

A UO_2 storage facility would generate a demand for 80 to 100 additional rental housing units during the peak year of construction, representing an impact of 1.4 to 6.5% on the projected number of vacant rental housing units at the representative sites (Table G.19). A demand for 30 to 40 additional owner-occupied housing units would be expected in the first year of operations, representing an impact of 0.2 to 0.7% on the number of vacant owner-occupied housing units at each site.

During the peak year of construction, between 210 and 280 persons would in-migrate into the ROI for the site, leading to an increase of 0.1 to 0.2% over ROI-forecasted baseline revenues and expenditures at the representative sites (Table G.19). In the first year of operations, 70 to 100 in-migrants would be expected, leading to an increase of less than 0.1 to 0.1% in local revenues and expenditures at the sites.

G.3.5.3 Long-Term Storage as U_3O_8

During the peak year of construction of a U_3O_8 long-term storage building or vault, 170 to 210 direct jobs would be created at the site and 140 to 280 additional jobs indirectly in the ROI surrounding the site (Table G.19) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, between 310 and 490 jobs would be created. Construction activity would also produce direct and indirect income in the ROI, with total income of \$11 million to \$15 million produced during the peak year. In the first year of operations of the facility, between 100 and 130 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI surrounding the site, with total income of \$5 million to \$8 million in the first year. Construction and operation of a U_3O_8 storage facility would result in an increase in the projected baseline compound annual average growth rate in employment in the ROI of 0.001 to 0.003 percentage points from 2006 through 2039.

Construction of a U_3O_8 storage facility would be expected to generate direct in-migration of 230 to 290 in the peak year of construction. Additional indirect job in-migration would be expected into the site ROIs, bringing the total number of in-migrants to between 300 and 420 in the peak year (Table G.19). Operation of the facility would be expected to generate direct job in-migration of 60 to 70 in the first year. Additional indirect job in-migration into the ROI would also be expected, bringing the total number of in-migrants to between 80 and 100 in the first year of operations. Construction and operation of a U_3O_8 storage facility would result in an increase in the projected baseline compound annual average growth rate in ROI population of 0.001 to 0.005 percentage points from 2006 through 2039.

A U_3O_8 storage facility would generate a demand for 110 to 150 additional rental housing units during the peak year of construction, corresponding to an impact of 1.3 to 8.2% on the projected number of vacant rental housing units at the representative sites (Table G.19). A demand for 30 to 40 additional owner-occupied housing units would be expected in the first year of operations, corresponding to an impact of 0.3 to 0.8% on the number of vacant owner-occupied housing units at the site.

During the peak year of construction, between 300 and 420 persons would in-migrate into the ROI at each site, leading to an increase of 0.1 to 0.3% over ROI-forecasted baseline revenues and expenditures at the representative sites (Table G.19). In the first year of operations, 80 to 100 in-migrants would be expected, leading to an increase of between less than 0.1 to 0.1% in local revenues and expenditures at the sites.

G.3.5.4 Long-Term Storage in a Mine

Construction-related impacts (engineering, construction, project management, and site preparation and restoration activities) and operations-related impacts (operation, emplacement and closure, and surveillance and maintenance activities) are shown in Table G.20 for storage in a mine. The location of a long-term storage mine has not yet been determined. The socioeconomic impacts of long-term storage in a mine were analyzed on a non-site-specific basis for a generic site. Impacts at the generic site are presented in terms of the impact of each storage option on direct (on-site) employment and income of construction and operation activities. Estimation of the indirect impacts that would occur off-site in the ROI around each facility would require site-specific information on

TABLE G.20 Potential Socioeconomic Impacts of Long-Term Storage in a Mine

Option/Parameter	Construction[a]	Operations[b]
Storage as UF_6		
Direct jobs	500	60
Direct income ($ million 1996)	29	3
Storage as U_3O_8		
Direct jobs	410	60
Direct income ($ million 1996)	19	3
Storage as UO_2		
Direct jobs	340	60
Direct income ($ million 1996)	20	4

[a] Impacts are for peak year of construction, 2007. Socioeconomic impacts from construction were assessed for 2007 through 2028.

[b] Impacts are the annual averages for the emplacement period (2009–2028). Annual averages for the surveillance and maintenance period (2029–2039) were estimated to be equal to or less than these values.

a variety of regional economic, demographic, housing, and jurisdictional characteristics and were therefore not included in the analysis. In addition, estimates of the relative impacts of direct employment and income at each facility compared with the local economic baseline are not provided (see Allison and Folga 1997).

G.3.6 Ecology

Moderate to large adverse impacts to ecological resources could result from construction of a facility for long-term storage as UF_6, U_3O_8, or UO_2. Impacts could include mortality of individual organisms, habitat loss, or changes in biotic communities. Impacts due to operation of a storage facility would be negligible.

G.3.6.1 Storage as UF_6

Site preparation for the construction of a facility to store UF_6 in buildings would require the disturbance of approximately 131 acres (53 ha), including the permanent replacement of about 62 acres (25 ha) of current land cover with structures and paved areas. Existing vegetation would be destroyed during land-clearing activities. The vegetation communities that would be eliminated by site preparation would depend on the location of the facility. Communities occurring on undeveloped land at the representative sites are relatively common and well represented in the vicinity of the sites; however, impacts to high-quality native plant communities might occur if facility construction required disturbance to vegetation communities outside of the currently fenced areas (see Section G.3.9 for a discussion of land use). Construction of the storage facility would not be expected to threaten the local population of any species. The loss of up to 131 acres (53 ha) of undeveloped land would constitute a large adverse impact to vegetation. Erosion of exposed soil at construction sites could reduce the effectiveness of restoration efforts and create sedimentation downgradient of the site. The implementation of standard erosion control measures, installation of storm-water retention ponds, and immediate replanting of disturbed areas with native species would help minimize impacts to vegetation. Impacts due to facility construction are shown in Table G.21.

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land clearing activities. More mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities and competition would increase in these areas, potentially reducing the chances of survival or reproductive capacity of displaced individuals. Some wildlife species would be expected to quickly recolonize replanted areas near the storage facility following completion of construction. The permanent loss of 62 acres (25 ha) to 131 acres (53 ha) of habitat would not be expected to threaten the local population of any wildlife species since similar habitat would be available in the vicinity of the representative sites. However, habitat use in the vicinity of the facility may be reduced for some species due to the construction of a perimeter fence enclosing

TABLE G.21 Impacts to Ecological Resources from Construction of Long-Term Storage Facilities for Depleted Uranium

Option/Resource	Buildings	Vaults	Mine	Yards
Storage as UF_6				
Vegetation	Loss of 131 acres Large adverse impact	Not applicable[a]	Loss of 96 acres Moderate to large adverse impact	Loss of 144 acres Large adverse impact
Wildlife	Loss of 62 to 131 acres Moderate to large adverse impact	Not applicable	Loss of 32 to 96 acres Moderate adverse impact	Loss of 77 to 144 acres Large adverse impact
Aquatic species	Negligible impact	Not applicable	Negligible impact	Negligible impact
Wetlands	Potential adverse impact	Not applicable	Potential adverse impact	Potential adverse impact
Protected species	Potential adverse impact	Not applicable	Potential adverse impact	Potential adverse impact
Storage as U_3O_8				
Vegetation	Loss of 148 acres Large adverse impact	Loss of 212 acres Large adverse impact	Loss of 124 acres Large adverse impact	Not applicable[a]
Wildlife	Loss of 72 to 148 acres Large adverse impact	Loss of 86 to 212 acres Large adverse impact	Loss of 54 to 124 acres Large adverse impact	Not applicable
Aquatic species	Negligible impact	Negligible impact	Negligible impact	Not applicable
Wetlands	Potential adverse impact	Potential adverse impact	Potential adverse impact	Not applicable
Protected species	Potential adverse impact	Potential adverse impact	Potential adverse impact	Not applicable
Storage as UO_2				
Vegetation	Loss of 79 acres Moderate adverse impact	Loss of 114 acres Large adverse impact	Loss of 74 acres Moderate adverse impact	Not applicable[a]
Wildlife	Loss of 35 to 79 acres Moderate adverse impact	Loss of 40 to 114 acres Large adverse impact	Loss of 25 to 74 acres Moderate adverse impact	Not applicable
Aquatic species	Negligible impact	Negligible impact	Negligible impact	Not applicable
Wetlands	Potential adverse impact	Potential adverse impact	Potential adverse impact	Not applicable
Protected species	Potential adverse impact	Potential adverse impact	Potential adverse impact	Not applicable

[a] Long-term storage as UF_6 in vaults and long-term storage as U_3O_8 or UO_2 in yards were not considered.

a 131-acre (53-ha) area. Overall, construction of a facility for UF_6 storage would be considered a moderate to large adverse impact to wildlife.

Impacts to surface water and groundwater quality during construction are expected to be negligible (Section G.3.4). Thus, construction derived impacts to aquatic biota would also be expected to be negligible. Wetlands could potentially be filled or drained during construction. In addition, impacts to wetlands due to alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur if the storage facility were located immediately adjacent to wetland areas. However, impacts to wetlands would be minimized by maintaining a buffer area around wetlands during construction of the facility. Unavoidable impacts to wetlands would require a *Clean Water Act* Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies.

Critical habitat has not been designated for any state or federally listed threatened or endangered species at any of the representative sites. Prior to construction of a storage facility, a survey for state and federally listed threatened, endangered, or candidate species, or species of special concern would be conducted so that, if possible, impacts to these species could be avoided. Where impacts were unavoidable, appropriate mitigation could be developed.

Small releases of HF would be expected to occur during operation of the building storage facility. The air concentration of HF from facility operations would be 0.00031 to 0.00081 $\mu g/m^3$, well below levels injurious to wildlife. Resulting impacts to wildlife would be negligible.

Impacts due to construction of a facility to store UF_6 in a mine would be similar to impacts from storage in buildings, although a smaller area would be affected. Facility construction would require the disturbance of approximately 96 acres (39 ha), including the permanent replacement of approximately 32 acres (13 ha) of current land cover with structures and paved areas (including rock spoil). A larger proportion of the mine storage facility would be available for wildlife habitat in comparison with the building storage facility. Species diversity and abundance, however, would be expected to be low because of human presence, proximity of buildings, and the relatively poor habitat quality of landscaped areas. Construction of a facility to store UF_6 in a mine would constitute a moderate to large adverse impact to vegetation and a moderate adverse impact to wildlife. Impacts due to facility construction are shown in Table G.21. Releases of contaminants are not expected to occur during operation of the mine storage facility, therefore, impacts to wildlife due to facility operation would be negligible.

Impacts due to construction of a facility to store UF_6 in yards would be similar to impacts from storage in buildings, although a larger area would be affected. Facility construction would require the disturbance of approximately 144 acres (58 ha), including the permanent replacement of approximately 90 acres (37 ha) with buildings and paved areas. Compared with the building storage facility, a smaller proportion of the yard storage facility would be available for wildlife habitat. Construction of a facility to store UF_6 in yards would constitute a large adverse impact to vegetation and wildlife. Potential impacts associated with facility construction are shown in Table G.21.

Small releases of HF, UO_2F_2, and U_3O_8 would be expected to occur during operation of the yard storage facility due to transfers of UF_6 from defective cylinders. The maximum annual average air concentration at a storage site boundary from operation of a yard storage facility would be approximately 2.7×10^{-6} $\mu g/m^3$ for HF, 5.3×10^{-7} $\mu g/m^3$ for UO_2F_2, and 1.8×10^{-9} $\mu g/m^3$ for U_3O_8. Impacts to wildlife from these emissions are expected to be negligible.

Storage facility accidents, as discussed in Section G.3.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on such factors as location of the accident, season, and meteorological conditions.

G.3.6.2 Storage as U_3O_8

The construction of a facility to store U_3O_8 in buildings would generally result in the types of impacts associated with UF_6 building storage. Site preparation for the construction of a facility to store U_3O_8 in buildings would require the disturbance of approximately 148 acres (60 ha), including the permanent replacement of approximately 72 acres (29 ha) of current land cover with structures and paved areas. Construction of the storage facility would not be expected to threaten the local population of any species. The loss of up to 148 acres (60 ha) of undeveloped land would constitute a large adverse impact to vegetation. Releases of contaminants are not expected to occur during operation of the storage facility, therefore, impacts to biotic resources due to facility operation would be negligible. Impacts due to facility construction are shown in Table G.21.

The permanent loss of 72 to 148 acres (29 to 60 ha) of habitat would not be expected to threaten the local population of any wildlife species since similar habitat would be available in the vicinity of the representative sites. However, habitat use in the vicinity of the facility might be reduced for some species due to the construction of a perimeter fence enclosing a 148-acre (60-ha) area. Therefore, construction of a facility for U_3O_8 storage in buildings would be considered a large adverse impact to wildlife.

Impacts to surface water and groundwater quality during construction are expected to be negligible (Section G.3.4). Thus, construction derived impacts to aquatic biota would also be expected to be negligible.

Impacts due to construction of a facility to store U_3O_8 in vaults would be similar to impacts from storage in buildings, although a larger area would be affected. Facility construction would require the disturbance of approximately 212 acres (86 ha), including the permanent replacement of approximately 86 acres (35 ha) with structures and paved areas. A larger proportion of the vault storage facility would be available for wildlife habitat in comparison with the building storage facility. Species diversity and abundance, however, would be expected to be low because of human presence, proximity of buildings, and the relatively poor habitat quality of landscaped areas. Construction of a facility to store U_3O_8 in vaults would constitute a large adverse impact to vegetation and wildlife. The larger size of the facility also would increase the potential for unavoidable direct and indirect impacts to wetlands due to facility location. Impacts due to facility construction are shown in Table G.21. Releases of contaminants are not expected to occur during operation of the vault storage facility, therefore, impacts to biotic resources due to facility operation would be negligible.

Impacts due to construction of a facility to store U_3O_8 in a mine would be similar to impacts from storage in buildings or vaults, although a smaller area would be affected. Facility construction would require the disturbance of approximately 124 acres (50 ha), including the permanent replacement of approximately 54 acres (22 ha) of current land cover with structures and paved areas (including rock spoil). A larger proportion of the mine storage facility would be available for wildlife habitat in comparison with the building storage facility. Species diversity and abundance, however, would be expected to be low because of human presence, proximity of buildings, and the relatively poor habitat quality of landscaped areas. Construction of a facility to store U_3O_8 in a mine would constitute a large adverse impact to vegetation and wildlife. Impacts due to facility construction are shown in Table G.21. Releases of contaminants are not expected to occur during operation of the mine storage facility, therefore, impacts to biotic resources due to facility operation would be negligible.

G.3.6.3 Storage as UO_2

The construction of a facility to store UO_2 in buildings would generally result in the types of impacts associated with UF_6 building storage. Site preparation for the construction of a facility to store UO_2 in buildings would require the disturbance of approximately 79 acres (32 ha), including the permanent replacement of approximately 35 acres (14 ha) with structures, including paved areas. Construction of the storage facility would not be expected to threaten the local population of any species. The loss of up to 79 acres (32 ha) of undeveloped land would constitute a moderate adverse impact to vegetation. Impacts due to facility construction are shown in Table G.21.

The permanent loss of 35 to 79 acres (14 to 32 ha) of habitat would not be expected to threaten the local population of any wildlife species because similar habitat would be available in the vicinity of the representative sites. However, habitat use in the vicinity of the facility might be reduced for some species due to the construction of a perimeter fence enclosing a 79-acre (32-ha) area. Therefore, construction of a facility for UO_2 storage would be considered a moderate adverse impact to wildlife.

Impacts to surface water and groundwater quality during construction are expected to be negligible (Section G.3.4). Thus, construction derived impacts to aquatic biota would also be expected to be negligible.

Impacts due to construction of a facility to store UO_2 in vaults would be similar to impacts from storage in buildings, although a larger area would be affected. Facility construction would require the disturbance of approximately 114 acres (46 ha), including the permanent replacement of approximately 40 acres (16 ha) of current land cover with structures and paved areas. A larger proportion of the vault storage facility would be available for wildlife habitat in comparison with the building storage facility. However, species diversity and population densities would be expected to be low because of human presence, proximity of buildings, and the relatively low habitat quality of landscaped areas. Construction of a facility to store UO_2 in vaults would constitute a large adverse impact to vegetation and wildlife. The larger size of the facility would also increase the potential for unavoidable proximity to wetlands and consequent direct and indirect impacts. Impacts due to facility construction are shown in Table G.21. Releases of contaminants are not expected to occur during operation of the vault storage facility, therefore, impacts to biotic resources due to facility operation would be negligible.

Impacts due to construction of a facility to store UO_2 in a mine would be similar to impacts from storage in buildings or vaults, although a smaller area would be affected. Facility construction would require the disturbance of approximately 74 acres (30 ha), including the permanent replacement of approximately 25 acres (10 ha) of current land cover with structures and paved areas (including rock spoil). A larger proportion of the mine storage facility would be available for wildlife habitat in comparison with the building storage facility. Species diversity and abundance, however, would be expected to be low because of human presence, proximity of buildings, and the relatively poor habitat quality of landscaped areas. Construction of a facility to store UO_2 in a mine would constitute a moderate adverse impact to vegetation and wildlife. Impacts due to facility construction are shown in Table G.21. Releases of contaminants are not expected to occur during operation of the mine storage facility, therefore, impacts to biotic resources due to facility operation would be negligible.

G.3.7 Waste Management

Impacts on waste management from wastes generated during the long-term storage of depleted UF_6 would be caused by the potential overload of waste treatment and/or disposal capabilities either at a site or on a regional or national scale.

G.3.7.1 Storage of UF_6 in Yards, Buildings, and Mines

G.3.7.1.1 Yards

Construction of the storage pads and associated support facilities would generate nonhazardous solid waste and sanitary wastewater. Construction would generate about 3,500 yd^3 (2,700 m^3) of concrete and other solid wastes. Because solid waste disposal facilities can generally be expanded as required, the impact of the construction wastes would be minimal at any site.

The operations to maintain and store depleted UF_6 cylinders would consist of inspections, stripping and repainting of the external coating of cylinders, and disposal of scrap metal from old steel cylinders. These operations would generate three primary radioactive waste streams: uranium-contaminated scrap metal (low-level radioactive waste [LLW]) from replaced cylinders, UO_2F_2 from replaced cylinders (LLW), and solid process residue (low-level mixed waste [LLMW]) from cylinder painting. In addition, long-term yard storage operations would generate nonhazardous solid CaF_2 waste and sanitary wastewater. The amount of waste generated would depend upon the time when the activities occurred. For each waste type, the amount of waste generated annually would be larger during Phase I of the operations (see Table G.22). The waste totals from Phase I were generally used for comparison with the site waste loads.

The 109 yd^3/yr (83 m^3/yr) of scrap metal LLW and the 0.17 yd^3/yr (0.13 m^3/yr) of uranyl fluoride generated during Phase I would add from 1 to 3.8% to representative site LLW generation (Table G.22). The maximum amount of LLW generated annually during the continued storage of depleted UF_6 at all three sites would represent less than 1% of the projected annual DOE LLW generation. The 46 yd^3/yr (35 m^3/yr) of LLMW generated during long-term yard storage of depleted UF_6 would add from less than 1 to 35% to the LLMW loads at the representative sites, but UF_6 would be less than 1% of the total nationwide LLMW load.

TABLE G.22 Estimated Annual Waste Loads from Long-Term Storage of UF_6 in Yards

	Waste Load of Depleted UF_6		
	Annual Load (m^3/yr)		Total Load (m^3)
Waste Type	2009-2028	2029-2039	2009-2039
Low-level waste			
Scrap metal	83	44	2,144
UO_2F_2	0.13	0.07	3.37
Low-level mixed waste (inorganic process residue)	8.8	35	561
Nonhazardous waste (CaF_2)	0.08	0.05	2.15
Sanitary wastewater	6,500	6,700	204,000

[a] NA = not applicable; NR = not reported.

Source: DOE (1997).

The 0.11 yd^3/yr (0.08 m^3/yr) of solid nonhazardous waste generated during Phase I would represent less than 1% of the annual waste loads at the representative sites. The 8,700 yd^3/yr (6,700 m^3/yr) of sanitary wastewater would represent less than 1.5% of the annual wastewater load of the sites.

Overall, the waste input resulting from the long-term yard storage of depleted UF_6 would have negligible impact on radioactive waste management capabilities at the representative sites. The impact on nonradioactive site waste management would also be negligible. The impacts of waste resulting from the long-term yard storage of depleted UF_6 on national waste management capabilities would be negligible.

G.3.7.1.2 Buildings and Mines

The wastes generated during construction of any of the different types of storage facilities would be typical of a large construction project. The only wastes would be construction debris and the sanitary wastes of the labor force. Estimates for the wastewater generated during construction of the different types of UF_6 storage facilities are shown in Table G.23.

Operation of the UF_6 storage facility would be divided into two phases. Phase I (2009-2028) would involve the receipt, inspection, and repackaging of the depleted uranium containers and relocation of these containers to the storage facility. The wastes generated during this operation would be sanitary wastes of the labor force and the empty containers from the repacking process.

Phase II operations (2029-2039) would involve cylinder inspection, removal, repackaging and replacing of damaged containers. Damaged cylinders were assumed to be LLW. Waste generated during this phase of operations would be sanitary wastes of the labor force and the empty failed

TABLE G.23 Estimated Total Wastewater Volumes from Construction of Long-Term Storage Facilities for UF_6, U_3O_8, and UO_2

Uranium Compound	Wastewater Volume (million L) Buildings	Vaults	Mine	Yards
UF_6	4.0	N/A[a]	8.5	24.0
U_3O_8	4.7	6.2	10	N/A
UO_2	2.1	2.7	5.0	N/A

[a] N/A = data not available.

cylinders. The conversion of "heels" of UF_6 in damaged cylinders would result in UO_2F_2 waste (LLW) and a CaF_2 waste. The wastes expected from the storage of UF_6 are listed in Table G.24.

G.3.7.2 Storage of U_3O_8 and UO_2 in Buildings, Mines, and Vaults

The discussion of waste generation during construction and operations given in Section G.3.7.1.2 on storage of depleted UF_6 also applies to the storage of U_3O_8 and UO_2. Estimates of wastewater generation during construction of U_3O_8 and UO_2 long-term storage facilities are given in Table G.23. Estimates of waste generation during storage of U_3O_8 and UO_2 are given in Table G.24. No UO_2F_2 or CaF_2 wastes would be generated in the storing of these waste forms.

G.3.7.3 Summary

Overall, the LLW generated annually during the operation of the different types of storage facilities (buildings and vaults) would be small (less than 1%) compared with the expected annual LLW generation at the representative sites. The waste input resulting from the long-term storage of any of the three types of uranium forms would have minimal impact on radioactive waste management capabilities at the representative sites. The impact on nonradioactive waste management would also be minimal. The impacts of waste resulting from the long-term storage of any of the final uranium forms on national waste management capabilities would be negligible.

The impacts of the LLW resulting from long-term storage of any of the final uranium waste forms in a mine would be negligible (less than 1%) compared with national DOE LLW management capabilities.

G.3.8 Resource Requirements

Resource requirements include all materials necessary to construct and operate the storage facilities. The requirements discussed in this section are for the storage of the three chemical forms of depleted uranium only and do not include resources required for conversion to U_3O_8 or UO_2, which would be required for storage as an uranium oxide. Resource requirements for the conversion options are presented in Appendix F, Section F.3.8.

In general, the amount of resources is directly related to the magnitude of construction, with the greatest resources required for the development of an underground mine, and the least required for UF_6 storage in yards. Materials required could include concrete, sand, cement, and steel. In general, none of the construction resources identified are in short supply, and any impacts on the local economies would be small. No strategic and critical materials are projected to be consumed for either construction or operations phases.

TABLE G.24 Annual Waste Loads from Long-Term Storage of UF_6, U_3O_8, and UO_2 in Buildings, Vaults, and Mines

Time Period	Low-Level Waste (m^3/yr)	UO_2F_2 (LLW) (kg/yr)	CaF_2 (Nonhazardous) (kg/yr)	Wastewater (million L/yr)
Storage as UF_6				
Phase I				
Buildings	2.95	140	71	4.2
Vaults	NA[a]	NA	NA	NA
Mine	2.95	140	70	4.25
Phase II				
Buildings	0.2	8.8	4.4	3.4
Vaults	NA	NA	NA	NA
Mine	0.185	9.0	4.45	3.2
Storage as U_3O_8				
Phase I				
Buildings	1.05	NA	NA	4.4
Vaults	1.1	NA	NA	4.3
Mine	1.05	NA	NA	4.75
Phase II				
Buildings	0.05	NA	NA	3.4
Vaults	0.05	NA	NA	3.3
Mine	0.05	NA	NA	3.55
Storage as UO_2				
Phase I				
Buildings	0.75	NA	NA	4.0
Vaults	0.8	NA	NA	3.9
Mine	0.75	NA	NA	4.25
Phase II				
Buildings	0.04	NA	NA	3.1
Vaults	0.04	NA	NA	2.9
Mine	0.037	NA	NA	3.15

[a] NA = not applicable.

Energy resources during construction and operations would include the consumption of diesel fuel and gasoline for construction equipment and transportation vehicles. The anticipated requirements would appear to be small and not impact local or national supplies.

Significant quantities of electrical energy are projected to be required during construction of the mine storage facility because the majority of the construction equipment utilized in the underground portion are powered by electricity to avoid polluting the air in the underground work area. Similarly, a relatively higher annual consumption of electricity is projected during underground operations, compared with the other storage facility options. The required electricity would presumably be purchased from commercial utilities.

During the operations phase, no chemicals are projected to be required. The amount of natural gas would be relatively small and would be expected to be readily available.

Estimated utilities and materials required for constructing storage facilities for UF_6, U_3O_8, and UO_2 are listed in Table G.25 for the storage options. Estimated utilities and materials required for operating the storage facilities for UF_6, U_3O_8, and UO_2 are shown in Table G.26. The resource requirements are presented separately for Phase I operations, which would be concurrent with the construction period, and for Phase II operations.

G.3.9 Land Use

Land area requirements for each uranium chemical form and relevant storage option are presented in Table G.27. These data do not include acreage required for the construction phase for any of the storage options because development of land would be incremental and space required for material excavation storage, equipment staging, and construction material laydown areas would be available on adjacent undeveloped parcels. Consequently, areal needs for construction would not be greater than that for operations.

Although no site has been chosen for the storage of UF_6, UO_2, or U_3O_8, selection of a storage facility site at or near a location that is already dedicated to similar use could result in reduced land use impacts because immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land use.

G.3.9.1 Storage as UF_6

Except for potential impacts from disposal of rock spoil and excavated material in a mine, impacts to land use from the construction and operation of facilities dedicated to storage of depleted uranium in a UF_6 chemical form would be negligible and limited to clearing of required land, potential minor and temporary disruptions to contiguous land parcels, and a slight increase in vehicular traffic.

TABLE G.25 Resource Requirements for Constructing UF_6, U_3O_8, and UO_2 Storage Facilities

Utilities/Material	Unit	Total Consumption: Yards/ Vaults[a]	Buildings	Mines
UF_6 Storage Facility				
Utilities				
Electricity	MWyr	0.40	5.4	840
Solids				
Concrete	m^3	59,000	69,000	140,000
Cement	metric tons	12,000	14,000	29,000
Macadam	m^3	3,100	3,100	1,600
Steel	metric tons	1,000	29,000	50,000
Liquids				
Diesel fuel	million L	0.06	10	340
Gasoline	thousand L	53	8.6	11
U_3O_8 Storage Facility				
Utilities				
Electricity	MWyr	6.3	5.4	1,000
Solids				
Concrete	m^3	82,000	110,000	170,000
Cement	metric tons	16,000	22,000	34,000
Macadam	m^3	3,400	12,000	1,700
Steel	metric tons	34,000	37,000	59,000
Liquids				
Diesel fuel	million L	12	150	410
Gasoline	thousand L	11	11	15
UO_2 Storage Facility				
Utilities				
Electricity	MWyr	3.0	2.5	490
Solids				
Concrete	m^3	37,000	48,000	85,000
Cement	metric tons	7,500	9,700	17,000
Macadam	m^3	2,200	5,600	1,500
Steel	metric tons	16,000	17,000	29,000
Liquids				
Diesel fuel	million L	5.3	66	200
Gasoline	thousand L	3.5	3.7	6.0

[a] UF_6 options include yards, buildings, and mines. U_3O_8 and UO_2 options include vaults, buildings and mines.

Sources: LLNL (1997); Folga (1996).

TABLE G.26 Resource Requirements for Operating UF_6, U_3O_8, and UO_2 Storage Facilities

		Annual Requirement					
		Yards		Buildings		Mines	
Utilities/Material	Unit	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
UF_6 Storage Facility							
Electricity	MWh	1,700	1,700	1,600	1,600	1,500	1,500
Natural gas	million scm	0.31	0.31	0.31	0.31	0.10	0.10
Diesel fuel	thousand L	57	60	52	0.02	25	0.01
Gasoline	thousand L	1.7	2.4	10	8	2.9	2:2
U_3O_8 Storage Facility							
Electricity	MWh	1,700	1,700	1,700	1,700	1,700	1,700
Natural gas	million scm	0.35	0.38	0.10	0.10	0.10	0.10
Diesel fuel	thousand L	65	0.02	120	0.04	14	0.004
Gasoline	thousand L	13	8.5	13	10	3.6	2.7
UO_2 Storage Facility							
Electricity	MWh	1,200	1,200	1,100	1,100	1,200	1,200
Natural gas	million scm	0.21	0.21	0.10	0.10	0.10	0.10
Diesel fuel	thousand L	39	0.01	93	0.04	14	0.005
Gasoline	thousand L	8.0	5.7	8.5	6.3	2.5	1.9

Source: LLNL (1997).

A storage building option would require 131 acres (53 ha) of land (see Table G.27). The storage yard option would require 144 acres (58 ha). The storage option utilizing a mine would require 96 acres (39 ha). The mine storage option would result in 1,990,000 yd^3 (1,520,000 m^3) of excavated material from the displacement of 114 underground acres (54 ha). Depending upon the location of the mine, disposal of such a large volume of material could result in land-use impacts ranging from changes in on-site topography to conflicts with existing local land-use plans. The amount of land required for the storage building option could result in potential land disturbance impacts, particularly if the site location featured land that was heavily wooded.

TABLE G.27 Land Requirements for the Long-Term Storage Options

	Land Requirement[a] (acres)				
				Mine	
Option	Yards	Buildings	Vaults	Aboveground	Underground
Storage as UF_6	144	131	N/A[b]	96	114
Storage as U_3O_8	N/A	148	212	124	138
Storage as UO_2	N/A	79	114	74	77

[a] There is no distinction between construction and operations because the storage areas would be cleared incrementally on the basis of need. Consequently, the acreage requirements listed here are the total number of acres required to meet the capabilities of the option.

[b] N/A = not applicable (option does not include this method of storage).

Source: LLNL (1997).

Road and rail access within a storage site, regardless of storage option, would be designed to minimize on-site traffic conflicts. For off-site traffic, potential impacts associated with construction vehicles could be encountered. The maximum labor force required for operation at a long-term storage facility, regardless of the storage option, would not be great enough to generate traffic impacts.

G.3.9.2 Storage as U_3O_8

Storage as U_3O_8 would require the greatest amount of land per option (see Table G.27) and would result in the greatest amount (2,350,000 yd^3 [1,800,000 m^3]) of excavated material and rock spoils. Disposal of the excavation material from a mine could result in minor land-use impacts that range from temporary disruptions of local traffic to minor land modification at the disposal site. Areal requirements for storage as U_3O_8 would range from 120 to 213 acres (48 to 86 ha). Consequently, the potential for land disturbance impacts would be greater than that expected for storage as either UF_6 or UO_2.

Road and rail access within a storage site, regardless of storage option, would be designed to minimize on-site traffic conflicts. For off-site traffic, only temporary minor impacts associated with construction vehicles could be encountered. The maximum labor force required for operation, regardless of the storage option, would not be great enough to generate traffic impacts.

G.3.9.3 Storage as UO_2

Storage as UO_2 would require the least amount of land per option (see Table G.27) and would result in the least amount (1,200,000 yd^3 [900,000 m^3]) of excavated material and rock spoils. Disposal of the excavation material from a mine could result in land-use impacts, but such impacts are expected to be negligible and of a lesser magnitude than would occur under storage as U_3O_8 or UF_6. Less land would have to be cleared for storage facilities (between 25 and 40 acres [10 and 16 ha]). Consequently, the potential for land disturbance impacts would be less than that expected for storage in either UF_6 or U_3O_8. The maximum labor force required for operations would not be great enough to generate off-site traffic impacts.

G.3.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur if the storage options considered in this PEIS were implemented include impacts to cultural resources and environmental justice, as well as impacts to the visual environment (e.g., aesthetics), recreational resources and noise levels, and impacts associated with decontamination and decommissioning of the storage facilities. These impacts, although considered, were not analyzed in detail for one or more of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier NEPA documentation when specific sites are considered.

- Consideration of these impacts would not contribute to differentiation among the alternatives and, therefore, would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

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APPENDIX H:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR THE MANUFACTURE AND USE OF URANIUM OXIDE AND URANIUM METAL

CONTENTS (APPENDIX H)

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FIGURE

NOTATION (APPENDIX H)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
HEPA	high-efficiency particulate air (filter)
HLW	high-level radioactive waste
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 μm or less

Chemicals

CO	carbon monoxide
HC	hydrocarbons
NO_x	nitrogen oxides
UF_6	uranium hexafluoride
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

ft	foot (feet)	lb	pound(s)
g	gram(s)	μg	microgram(s)
gal	gallon(s)	μm	micrometer(s)
gpm	gallon(s) per minute	m	meter(s)
ha	hectare(s)	m^3	cubic meter(s)
km	kilometer(s)	mi^2	square mile(s)
km^2	square kilometer(s)	min	minute(s)

mrem	millirem(s)
MW	megawatt(s)
MWyr	megawatt year(s)
rem	roentgen equivalent man
s	second(s)
scf	standard cubic foot (feet)
ton(s)	short ton(s)
yd^3	cubic yard(s)
yr	year(s)

APPENDIX H:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR THE MANUFACTURE AND USE OF URANIUM OXIDE AND URANIUM METAL

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the manufacture and use options considered in the PEIS. The discussion provides background information for the manufacture and use of oxide and metal, as well as a summary of the estimated environmental impacts associated with each option.

Manufacture and Use Options

The representative manufacture and use options analyzed in detail in the PEIS consider using depleted uranium as radiation shielding material. Even though uranium is radioactive itself, it can be used effectively to shield gamma radiation from highly radioactive material — such as spent nuclear fuel — because it is very dense. Two representative options are considered:

Uranium Oxide Shielding Option. This option considers the manufacture and use of uranium oxide storage casks for spent nuclear fuel using a uranium concrete material similar to conventional concrete but containing high-density uranium oxide (UO_2) in place of normal aggregate (typically gravel).

Uranium Metal Shielding Option. This option considers the manufacture and use of uranium metal casks for the storage, transport, and disposal of spent nuclear fuel (sometimes called a multi-purpose unit).

Several current and potential uses exist for depleted uranium. Depleted uranium could be mixed with highly enriched uranium from retired nuclear weapons to produce nuclear reactor fuel. This process is called blending, and, to date, only natural uranium has been considered for this application. Depleted uranium is currently used as a counterweight in high-performance aircraft. Such uses can be expected in the future, and there are other potential uses as counterweights on forklifts and as flywheels. Military applications of depleted uranium include use as tank armor, armor piercing projectiles (antitank weapons), and counterweights in missiles.

The two use alternatives evaluated in detail in the PEIS, use as uranium oxide and use as uranium metal as radiation shielding, were selected as representative options for the purposes of comparing the potential environmental impacts of broad alternative management strategies. These options were selected in part because a recent market study suggests that the largest potential market for depleted uranium currently appears to be in shielding applications (Kaplan 1995). However, the selection of these use options for analysis in the PEIS was not intended to imply that the PEIS will be used to select a specific end use or preclude other potential uses in the future. If a use strategy is selected in the Record of Decision, specific uses would be considered and evaluated in more detail in future planning and environmental analyses, as appropriate.

Shielding is any material that is placed between a source of radiation and people, equipment, or other objects, in order to absorb the radiation and thereby reduce radiation exposure. Common shielding materials include concrete, steel, water, and lead. For shielding gamma radiation sources, the more dense a material is, the more effective it is as a shield. Therefore, even though uranium is radioactive itself, it can be used effectively to shield more highly penetrating radiation because of its density. Uranium is one of the most dense materials known, being 1.6 times more dense than lead.

The PEIS evaluates two options for the manufacture and use of depleted uranium shielding: (1) the uranium oxide option, which is based on the use of dense uranium dioxide (UO_2); and (2) the uranium metal option, based on the use of uranium metal. Both options assume that the depleted uranium would be used as the primary shielding material in containers (called "casks") used to store spent nuclear fuel. Spent nuclear fuel is the highly radioactive "used" fuel produced in nuclear power plants. Although spent nuclear fuel is most commonly shielded by water in large storage pools, there is a growing need for heavily shielded storage casks. A typical storage cask is a cylindrical container about 15 ft (4.5 m) high and 5 ft (1.5 m) in diameter (see Figure H.1). For both options, the cask designs are based on existing designs, and assume that the uranium shielding material would be enclosed between stainless steel (or equivalent) shells (Lawrence Livermore National Laboratory [LLNL] 1997).

The uranium oxide option assumes that depleted uranium in the form of high density UO_2 would be used for the manufacture of depleted uranium concrete for shielding in spent nuclear fuel storage casks. This uranium concrete material, which substitutes dense UO_2 for the coarse aggregate (typically gravel) in conventional concrete, is known as DUCRETE. As a shielding material, DUCRETE offers size and weight advantages compared to conventional concrete. Shielding made of DUCRETE would typically require less than half the thickness of shielding made from concrete to obtain the same effect.

The uranium metal option assumes that depleted uranium in the form of metal would be used for the manufacture of shielding in a spent nuclear fuel cask that could be used not only for storage, but also for transportation and disposal. This type of cask is commonly called a multi-purpose unit. No assumptions were made regarding the fate of the uranium oxide or uranium metal casks after use. The empty casks could be recycled, stored, or disposed of as low-level radioactive waste (LLW).

For assessment purposes, the manufacture of depleted uranium shielded casks was assumed to take place at a stand-alone industrial plant dedicated to the cask fabrication process. In general,

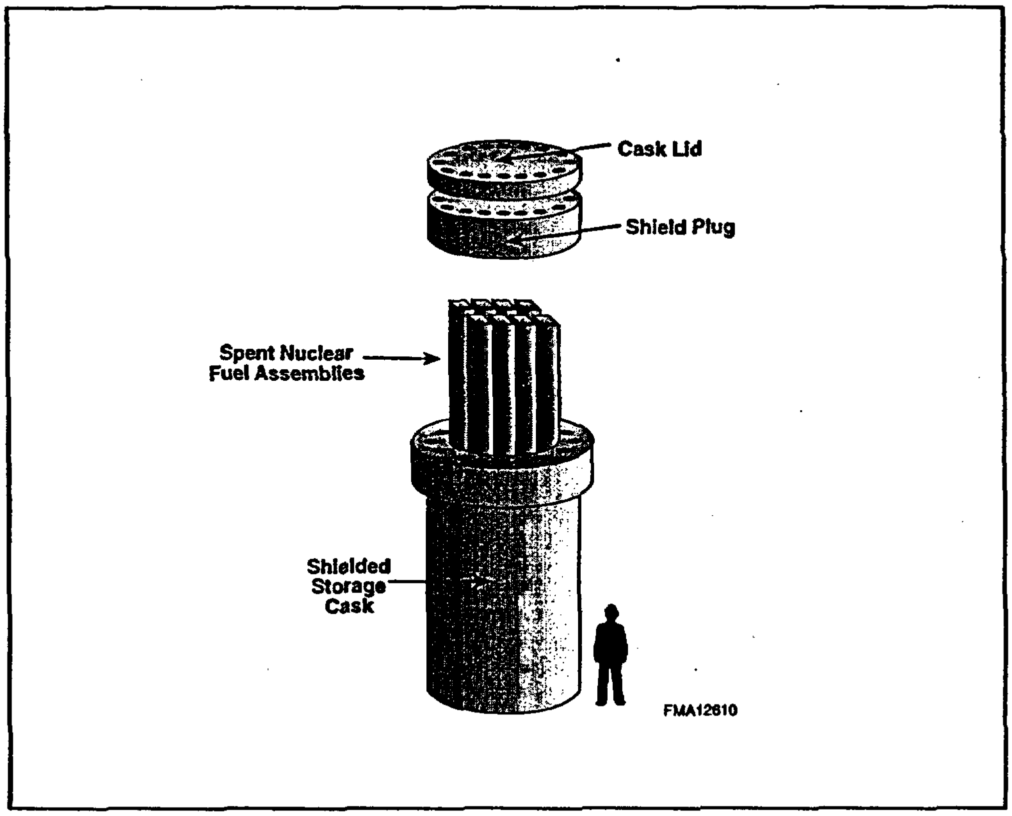

FIGURE H.1 Representative Spent Nuclear Fuel Storage Cask (Shielding is typically provided by concrete, DUCRETE [concrete with depleted UO_2], or uranium metal.)

the plant would be capable of receiving packages of depleted uranium (either UO_2 or metal) on trucks or railcars from a conversion facility, fabricating shielded casks, and storing the casks until shipment by rail to a user, such as a nuclear power plant. At the user facility, the casks would be used to store spent nuclear fuel.

The potential impacts from a manufacturing facility were analyzed for generic dry and wet environmental settings. The conditions at the dry environmental setting would be typical of a site in the western United States, and the conditions at the wet environmental setting would be typical of a site in the eastern United States.

In general, potential environmental impacts would occur (1) during construction of the cask manufacturing facility, (2) during routine operation of the cask manufacturing facility, and (3) as a result of potential manufacturing plant accidents. The potential impacts during construction would be generally limited to the duration of the construction period and would result from typical land-clearing and construction activities. Potential impacts during operations would result from handling the incoming containers of depleted uranium and from small emissions of uranium compounds to the air and water. Impacts might also occur from potential manufacturing accidents that may result in the release of hazardous materials to the environment. Impacts during the use of depleted uranium shielded casks were not quantified in the PEIS. In general, the potential impacts associated with any structural components of a depleted uranium cask would be negligible compared with the potential impacts associated with the spent nuclear fuel stored within the casks during use. Excluding accidents, no release of depleted uranium material would occur during use.

The potential environmental impacts presented in this chapter were evaluated based on the information described in the engineering analysis report (LLNL 1997). For each manufacture and use option, the engineering analysis report provides preconceptual manufacturing facility design data, including descriptions of facility layouts; shielding cask design details; resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios.

H.1 SUMMARY OF MANUFACTURE AND USE OPTION IMPACTS

This section provides a summary of the potential environmental impacts associated with two manufacture and use options: (1) a uranium oxide shielding option and (2) a uranium metal shielding option. The assessment of impacts was limited to the potential impacts from construction and operation of cask manufacturing facilities. Additional discussion and details related to the assessment results for individual areas of impact are provided in Section H.3.

Potential environmental impacts from the two manufacture and use options are summarized in Table H.1. Based on the information in Table H.1 and Section H.3, the following conclusions can be drawn:

- For both manufacture and use options, potential human health and safety impacts to workers and the public would be small during construction and normal operations. The consequences of accidents involving release of radioactive or chemical materials would be low. About 1 fatality during construction and operations was estimated from an on-the-job occupational accident.

- For both options, potential impacts other than human health and safety tend to be small and similar between the options.

H.2 DESCRIPTION OF OPTIONS

This section provides a brief summary of the options considered in the assessment of manufacture and use impacts. The information is based on preconceptual design data provided in the engineering analysis report (LLNL 1997). The engineering analysis report contains much more

TABLE H.1 Summary of Manufacture and Use Option Impacts

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 460 person-rem	**Involved Workers:** Total collective dose: 100 person-rem
Total number of LCFs: 0.2	Total number of LCFs: 0.04
Noninvolved Workers: Annual dose to MEI: $6.1 \times 10^{-5} - 2.8 \times 10^{-4}$ mrem/yr	**Noninvolved Workers:** Annual dose to MEI: $1.3 \times 10^{-4} - 6.4 \times 10^{-4}$ mrem/yr
Annual cancer risk to MEI: $2 \times 10^{-11} - 1 \times 10^{-10}$ per year	Annual cancer risk to MEI: $5 \times 10^{-11} - 3 \times 10^{-10}$ per year
Total collective dose: $2.0 \times 10^{-5} - 2.5 \times 10^{-4}$ person-rem	Total collective dose: $1.2 \times 10^{-4} - 1.5 \times 10^{-3}$ person-rem
Total number of LCFs: $8 \times 10^{-9} - 1 \times 10^{-7}$ LCF	Total number of LCFs: $5 \times 10^{-8} - 6 \times 10^{-7}$ LCF
General Public: Annual dose to MEI: $1.9 \times 10^{-4} - 8.7 \times 10^{-4}$ mrem/yr	**General Public:** Annual dose to MEI: $3.8 \times 10^{-4} - 1.9 \times 10^{-3}$ mrem/yr
Annual cancer risk to MEI: $1 \times 10^{-10} - 4 \times 10^{-10}$ per year	Annual cancer risk to MEI: $2 \times 10^{-10} - 1 \times 10^{-9}$ per year
Total collective dose to population within 50 miles: 0.00098 – 0.12 person-rem	Total collective dose to population within 50 miles: 0.0059 – 0.73 person-rem
Total number of LCFs in population within 50 miles: $5 \times 10^{-7} - 6 \times 10^{-5}$ LCF	Total number of LCFs in population within 50 miles: $3 \times 10^{-6} - 4 \times 10^{-4}$ LCF
Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts

TABLE H.1 (Cont.)

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: less than 1 in 1,000,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Dose to MEI: 0.077 rem	Dose to MEI: 0.23 rem
Risk of LCF to MEI: 0.00003 per year	Risk of LCF to MEI: 0.00009 per year
Collective dose: 0.029 person-rem	Collective dose: 0.087 person-rem
Number of LCFs: 0.00001	Number of LCFs: 0.00003
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Dose to MEI: 0.0023 rem	Dose to MEI: 0.007 rem
Risk of LCF to MEI: 1×10^{-6} per year	Risk of LCF to MEI: 4×10^{-6} per year
Collective dose to population within 50 miles: 0.32 person-rem	Collective dose to population within 50 miles: 1.9 person-rem
Number of LCFs among population within 50 miles: 0.0002 LCF	Number of LCFs among population within 50 miles: 0.001 LCF
Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: less than 1 in 1,000,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 4 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 2 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 1 person
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 1 person

TABLE H.1 (Cont.)

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Approximately 1 fatality, approximately 640 injuries	**Construction and Operations:** **All Workers:** Approximately 1 fatality, approximately 670 injuries
Air Quality	
Construction: Concentrations of criteria pollutants all 9% or less of respective standards	**Construction:** Concentrations of criteria pollutants all 9% or less of respective standards
Operations: Pollutant concentrations 4% or less of values during construction	**Operations:** Pollutant concentrations 4% or less of values during construction
Water[a]	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
Soil[a]	
Construction: Negligible but temporary impacts	**Construction:** Negligible but temporary impacts
Operations: No impacts	**Operations:** No impacts
Socioeconomics	
Construction: Potentially moderate impacts on employment and income	**Construction:** Potentially moderate impacts on employment and income
Operations: Potentially moderate impacts on employment and income	**Operations:** Potentially moderate impacts on employment and income
Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife
Operations: Negligible impacts	**Operations:** Negligible impacts
Waste Management	
Negligible impacts on regional or national waste management operations	Negligible impacts on regional or national waste management operations

TABLE H.1 (Cont.)

Impacts from Manufacture and Use of Oxide Shielding	Impacts from Manufacture and Use of Uranium Metal Shielding
Resource Requirements	
No impacts from resource requirements (such as electricity or materials) would be expected on the local or national scale	No impacts from resource requirements (such as electricity or materials) would be expected on the local or national scale
Land Use	
Use of approximately 90 acres; potential moderate impacts, including traffic impacts	Use of approximately 90 acres; potential moderate impacts, including traffic impacts

[a] Impacts if the generic site was large relative to the proposed facility and was located near a river where minimum flow was large relative to water use..

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 µm or less; ROI = region of influence.

detailed information, including descriptions of manufacturing facility layouts; shielding cask design details; resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios. The manufacture and use options assume that depleted uranium in the form of UO_2 or metal would be shipped to the manufacturing plant from a conversion facility. The environmental impacts associated with the conversion process are provided in Appendix F.

H.2.1 Uranium Oxide Shielding Option

The uranium oxide shielding option would require a total site area of about 90 acres (37 ha), of which 32 acres (13 ha) would be disturbed or cleared. The manufacturing facility would receive high-density UO_2 from a conversion plant, and the partially fabricated stainless steel shells and other shielding cask components from a supplier. The steel cask shell would be fabricated using conventional industry practices, including welding, machining and final assembly. At the cask manufacturing facility, uranium oxide shielding would be prepared using high-shear mixing for evenly combining the high-density UO_2 and concrete components. The mixture would then be poured between an inner and outer steel cask shell. Final assembly of the shielding cask would be performed after the mixture cured. The oxide shielding composition would be nominally 74% UO_2, 11% sand, 10% cement and additives, and the remainder water. Each cask would contain about 50 tons (45 metric tons) of UO_2, with about 480 casks being manufactured each year. The casks would then be sent to a user, such as a nuclear power plant.

H.2.2 Uranium Metal Shielding Option

The metal shielding option would require a total site area of about 90 acres (37 ha), of which 36 acres (15 ha) would be disturbed or cleared. The manufacturing facility would receive uranium metal ingots (or alloy) from a conversion plant, and partially fabricated stainless steel or titanium alloy shells and other shielding cask components from a supplier. The inner and outer steel shells of the casks would be assembled using standard operations, such as welding, machining and final assembly. In a separate building, the uranium metal would be melted and directly cast between the inner and outer shells of the assembled cask. After cooling, final assembly of the shielding cask would be carried out. Each finished shielding cask would contain about 47 tons (43 metric tons) of uranium metal, with about 453 casks being manufactured each year.

H.2.3 Manufacture and Use Options Considered But Not Analyzed

Several manufacture and use options were not analyzed in depth in the engineering analysis report: (1) use of depleted uranium in light water reactor fuel, (2) use of depleted uranium as fuel in advanced breeder reactors, and (3) dense material applications other than radiation shielding. As discussed more fully in Section 2.3.2 of the PEIS, these uses are either too uncertain at this time for full analysis or are represented by the options analyzed in the PEIS.

H.3 IMPACTS OF OPTIONS

This section provides a summary of the potential environmental impacts associated with the manufacture and use options, including impacts from construction and facility operations. Information related to the assessment methodologies for each area of impact is provided in Appendix C.

The environmental impacts from the manufacture and use options were evaluated based on the information described in the engineering analysis report (LLNL 1997). The following general assumptions apply to the assessment of impacts:

- Shielding cask manufacturing facilities would operate over a 20-year period, from 2009 through 2028, using either depleted uranium oxide or metal from the DOE-generated inventory. Preoperation of manufacturing facilities would occur between 1999 and 2008, with actual construction requiring 7 years.

- The uranium oxide and uranium metal cask manufacturing plants would produce 480 and 453 casks per year, respectively, over the operational period.

- The cask manufacturing facilities were assumed to be stand-alone facilities built for the specific purpose of fabricating casks. The manufacturing facilities would receive depleted uranium in the form of UO_2 or metal from a conversion facility.

- Potential impacts from a manufacturing facility were analyzed for generic dry and wet environmental settings and for generic rural and urban settings. The historical meteorological conditions for five actual "dry" locations in the southwestern United States and five actual "wet" locations in the central and southeastern United States were averaged to develop estimates for the generic settings. The generic rural setting was assumed to have a population density corresponding to 15 persons/mi^2 (6 persons/km^2); the generic urban setting was assumed to have a population density corresponding to 700 persons/mi^2 (275 persons/km^2).

- The assessment of impacts was limited to potential impacts from the construction and operation of a cask manufacturing facility. Impacts during the use of depleted uranium shielded casks have not been estimated in the PEIS because the impacts associated with the depleted uranium cask components would be negligible compared with the potential impacts associated with the spent nuclear fuel within a cask and because no release of depleted uranium material would occur during use. Use of spent nuclear fuel storage casks would be subject to DOE or U.S. Nuclear Regulatory Commission (NRC) review and approval.

- The impacts presented herein for manufacturing of oxide- and metal-shielded containers would be representative of any impacts associated with manufacture of other products that contain depleted uranium because none of the other potential uses would consume as much depleted UF_6 inventory as the oxide and metal container use.

- Because of existing regulations in the United States, it is highly unlikely that products containing depleted uranium would be available for unrestricted use at this time. Impacts to the general public from restricted use applications would be negligible. Impacts to the workers from uranium oxide or uranium metal casks at the user locations (e.g., commercial nuclear power generators) would depend largely on the particular application but would be less than those to workers at the manufacturing facilities. Any commercial use of depleted uranium would take place under an NRC license or a waiver from the NRC. Potential impacts from such use would have to be analyzed before a license or waiver could be obtained.

H.3.1 Human Health — Normal Operations

H.3.1.1 Radiological Impacts

Radiological impacts were assessed for involved workers, noninvolved workers, and the general public. Impacts to involved workers would result primarily from exposures to external radiation in the vicinity of uranium material for both options considered. The average radiation dose would be less than 110 mrem/yr. Impacts to noninvolved workers and the general public would result from release of uranium compounds to the environment. The maximum radiation dose would be very small, less than 0.002 mrem/yr. The estimated radiation doses and cancer risks are listed in Tables H.2 and H.3, respectively. Detailed discussions of the methodologies used in radiological impact analyses are provided in Appendix C and Cheng et al. (1997).

TABLE H.2 Radiological Doses from Manufacture and Use Options under Normal Operations

	Dose to Receptor[a]					
	Involved Worker[b]		Noninvolved Worker[c]		General Public	
Shielding Option	Average Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[d] (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[e] (mrem/yr)	Collective Dose[f] (person-rem/yr)
Uranium oxide casks	110	23	6.1×10^{-5} – 2.8×10^{-4}	1.0×10^{-6} – 1.2×10^{-5}	1.9×10^{-4} – 8.7×10^{-4}	4.9×10^{-5} – 6.1×10^{-3}
Uranium metal casks	23	5.0	1.3×10^{-4} – 6.4×10^{-4}	6.2×10^{-6} – 7.5×10^{-5}	3.8×10^{-4} – 1.9×10^{-3}	3.0×10^{-4} – 3.7×10^{-2}

[a] Impacts are reported as ranges, which result from differences for five generic dry and wet environmental settings.

[b] Involved workers are those workers directly involved with the handling of materials. Results are presented as average individual dose and collective dose for the worker population. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[c] Noninvolved workers are individuals who do not participate in material-handling activities, such as managers and secretaries. The number of noninvolved workers would be about 200 for both uranium oxide casks and uranium metal casks.

[d] The MEI for the noninvolved workers was assumed to be located on-site at the location that would yield the largest dose from airborne emissions, including doses from inhalation, external radiation, and incidental ingestion of soil.

[e] The MEI for the general public was assumed to be located off-site at the point that would yield the largest dose from exposures through inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

[f] The collective dose was estimated for the off-site population within a 50-mile (80-km) radius around the facility. The range of collective doses results from differences in dry and wet locations surrounded by a rural (about 120,000 people) or urban (about 5,600,000 people) population. The exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk and soil.

TABLE H.3 Latent Cancer Risks from Manufacture and Use Options under Normal Operations

	Risk to Receptor[a]					
	Involved Worker[b]		Noninvolved Worker[c]		General Public	
Shielding Option	Average Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[d] (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Uranium oxide casks	4×10^{-5}	9×10^{-3}	2×10^{-11} – 1×10^{-10}	4×10^{-10} – 5×10^{-9}	1×10^{-10} – 4×10^{-10}	2×10^{-8} – 3×10^{-6}
Uranium metal casks	9×10^{-6}	2×10^{-3}	5×10^{-11} – 3×10^{-10}	2×10^{-9} 3×10^{-8}	2×10^{-10} – 1×10^{-9}	2×10^{-7} – 2×10^{-5}

[a] Impacts are reported as ranges, which result from differences for five generic dry and wet environmental settings.

[b] Involved workers are those workers directly involved with the handling of materials. Results are presented as average individual risk and collective risk for the worker population.

[c] Noninvolved workers are individuals who do not participate in material-handling activities, such as managers and secretaries. The number of noninvolved workers is about 200 for both uranium oxide casks and uranium metal casks.

[d] The MEI for the noninvolved workers was assumed to be located on-site at the location that would yield the largest risk from airborne emissions, including risks from inhalation, external radiation, and incidental ingestion of soil.

[e] The MEI for the general public was assumed to be located off-site at the point that would yield the largest risk from exposures through inhalation, external radiation, and ingestion of plant foods, meat, milk, soil, and drinking water.

[f] The collective risk was estimated for the population within a 50-mile (80-km) radius around the facility. The range of collective risks results from differences in dry and wet locations surrounded by a rural (about 120,000 people) or urban (about 5,600,000 people) population. The exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk and soil.

H.3.1.1.1 Impacts from Manufacturing

Uranium Oxide. For the uranium oxide option, the collective dose to involved workers was estimated to be approximately 23 person-rem/yr for a total of 220 workers, which corresponds to about 0.009 additional latent cancer fatality (LCF) per year among workers (i.e., 1 LCF would be expected in 110 years of operation). The average involved worker dose was estimated to be about 110 mrem/yr, well below the regulatory limit of 5,000 mrem/yr specified for workers (10 *Code of Federal Regulations* [CFR] Part 835). The average risk to an involved worker of developing an LCF would be about 4×10^{-5} per year (one chance in 25,000 per year).

Radiation doses to noninvolved workers and members of the general public would depend on the location of the facility and would be very small because of the small amount of uranium released. The radiation dose to the maximally exposed individual (MEI) of noninvolved workers would be less than 2.8×10^{-4} mrem/yr, whereas the dose to the MEI of the general public would be less than 8.7×10^{-4} mrem/yr.

Uranium Metal. Because of the smaller volume handled and better self shielding characteristics of uranium metal (the density of uranium metal is about twice that of uranium oxide), the manufacturing of uranium metal casks would result in less radiation exposures to involved workers than the manufacturing of uranium oxide casks. The collective dose to involved workers was estimated to be about 5.0 person-rem/yr for approximately 220 workers. The average dose received by an involved worker would be about 23 mrem/yr, corresponding to an LCF risk of 9×10^{-6} per year (1 chance in 110,000 per year).

Radiation exposures to noninvolved workers and members of the general public from the uranium metal facility would be greater than those from the uranium oxide facility because of the higher emission rate of uranium. However, the radiation doses to the MEIs would be very small, less than 6.4×10^{-4} mrem/yr for noninvolved workers and less than 1.9×10^{-3} mrem/yr for the general public.

H.3.1.1.2 Impacts from Use

The spent nuclear fuel shielding casks made with uranium metal or uranium oxide would have the same shielding capability as conventional casks made with concrete, lead, or other shielding material. Although depleted uranium would be incorporated into the manufactured casks, the resulting exposure to personnel from the depleted uranium would be negligible when compared with the exposures from the spent nuclear fuel stored in the cask.

H.3.1.2 Chemical Impacts

Potential chemical impacts to human health from normal operations would result primarily from uranium releases from the manufacturing facilities. Risks from normal operations were quantified on the basis of calculated hazard indexes. Information on the exposure assumptions, health effects assumptions, reference doses used for uranium compounds, and calculational methods used in the chemical impact analysis is provided in Appendix C and Cheng et al. (1997).

H.3.1.2.1 Impacts from Manufacturing

Airborne emissions of uranium compounds from the metal facility would be more than 5 times greater than uranium emissions from the uranium oxide facility (LLNL 1997). Therefore, chemical exposures for the noninvolved workers and off-site general public would be higher due to releases from the metal facility. However, human health impacts would still be negligible for the noninvolved workers and off-site public for both manufacture and use options.

Uranium Oxide. Estimates of the impacts to human health from hazardous chemicals during operations at the uranium oxide facility are summarized in Table H.4. The overall hazard indices for chemical impacts to the noninvolved worker MEI were estimated to be less than

TABLE H.4 Chemical Impacts to Human Health from Manufacture and Use Options under Normal Operations

	Impacts to Receptor[a]			
	Noninvolved Workers[b]		General Public	
Shielding Option	Hazard Index for MEI[c,d]	Collective Risk[e] (ind. at risk/yr)	Hazard Index for MEI[c,f]	Collective Risk[e] (ind. at risk/yr)
Uranium oxide casks	$7.7 \times 10^{-9} - 3.4 \times 10^{-8}$	–	$6.2 \times 10^{-7} - 2.9 \times 10^{-6}$	–
Uranium metal casks	$1.6 \times 10^{-8} - 7.9 \times 10^{-8}$	–	$1.4 \times 10^{-6} - 6.7 \times 10^{-6}$	–

[a] Impacts are reported as ranges, which result from differences for five generic dry and wet environmental settings.

[b] Noninvolved workers are individuals who do not participate in material-handling activities, such as managers and secretaries.

[c] The hazard index is an indicator for potential health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

[d] The MEI for the noninvolved workers was assumed to be located on-site at the location that would yield the largest exposure from airborne emissions, including exposures through inhalation and incidental ingestion of soil.

[e] Calculation of collective risk is not applicable when the corresponding hazard index for the MEI is less than 1.

[f] The MEI for the general public was assumed to be located off-site at the point that would yield the largest exposures through inhalation and ingestion of soil and drinking water.

3.4×10^{-8} for all dry and wet representative locations. Because these values are considerably below the threshold for adverse effects (i.e., the ratio of intake to reference dose is less than 1), no health effects would be expected. The overall hazard indices for chemical impacts to the general public MEI are estimated to be less than 2.9×10^{-6} for all dry and wet representative sites. These values are also considerably below the threshold for adverse effects.

Uranium Metal. Estimates of the hazardous chemical human health impacts resulting from operations at the uranium metal facility are summarized in Table H.4. Hazard indices are approximately 2 times higher for the uranium metal option than for the uranium oxide option but still many orders of magnitude below the threshold for adverse effects.

H.3.1.2.2 Impacts from Use

Only the operations of the two types of manufacturing facilities would result in airborne and waterborne emissions of uranium; the use of shielding casks made with uranium metal or uranium oxide would not be expected to release any materials and, therefore, would not result in any impacts to the noninvolved workers and general public.

H.3.2 Human Health — Accident Conditions

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents has been presented in the engineering analysis report (LLNL 1997). These accidents are listed in Table H.5. The following sections present the results for the radiological and chemical health impacts of the highest consequence accident in each frequency category. Results for all accidents listed in Table H.5 are presented in Policastro et al. (1997). A detailed description of the methodology and assumptions used in the calculations is also provided in Appendix C and Policastro et al. (1997).

H.3.2.1 Radiological Impacts

The radiological doses to various receptors for the accidents that give the highest dose from each frequency category are listed in Table H.6. The LCF risks for these accidents are given in Table H.7. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions (wet and dry) and two different population distributions (rural and urban) were considered for each manufacture and use option. The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely category have a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

- The maximum radiological dose to noninvolved worker and general public MEIs (assuming an accident occurred) would be 230 mrem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the NRC (1994).

- The overall radiological risk to noninvolved worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table H.7] by the annual probability of occurrence by the number of years of operations) would be less than 1 for all of the manufacture and use accidents.

H.3.2.2 Chemical Impacts

The accidents considered in this section are listed in Table H.5. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables H.8 and H.9. The results are expressed as (1) number of persons with potential for adverse effects and (2) number of persons with potential for irreversible adverse effects. The tables present the results for the accident within each frequency category that would affect the largest number of people (total of noninvolved workers and population) (Policastro et al. 1997). The numbers of noninvolved workers and members of the

TABLE H.5 Accidents Considered for the Manufacture and Use Options

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Manufacture and Use as Oxide Shielding					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/billet inside the plant	A single UO_2 drum is damaged by a forklift and spills its contents onto the ground inside the UO_2 cask manufacturing plant.	UO_2	7.3×10^{-7}	Puff	Stack
Mixer/melter charge accident	Mishandling of the input load to the oxide mixer results in an airborne release of the input drum contents.	UO_2	0.000073	Puff	Stack
Mixer/melter operational accident	Failure of the oxide mixer during operation results in an airborne release of the mixer contents.	UO_2	0.00015	Puff	Stack
Mixer/melter discharge accident	Failure during discharge of the oxide mixers results in an airborne release.	UO_2	0.00044	Puff	Stack
Shield failure after casting	After the cask annulus has been filled with depleted uranium, it fails due to rupture or chemical reactivity.	UO_2	9.7×10^{-6}	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The UO_2 cask manufacturing plant is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	UO_2	0.33	30	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the UO_2 cask manufacturing plant structure and confinement systems.	UO_2	1.6	0.5	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire/explosion/chemical reagent contact inside the mixers	A leak or rupture of the oxide mixers results in a fire and/or explosion, but the HEPA filtration system is not affected.	UO_2	0.00044	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA

TABLE H.5 (Cont.)

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Manufacture and Use as Metal Shielding					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/billet inside the plant	A pallet of uranium metal billets is damaged by a forklift and spills its contents onto the ground inside the uranium metal cask manufacturing plant.	U_3O_8	0.0012	Puff	Stack
Mixer/melter charge accident	Mishandling of the input load to the uranium furnace results in an airborne release of the input billets.	U_3O_8	0.00009	Puff	Stack
Mixer/melter operational accident	Failure of the uranium furnace during operation results in an airborne release of the furnace contents.	U_3O_8	0.0004	Puff	Stack
Mixer/melter discharge accident	Failure during discharge of the uranium furnace results in an airborne release.	U_3O_8	0.0004	Puff	Stack
Shield failure after casting	After the cask annulus has been filled with molten depleted uranium it fails due to rupture or chemical reactivity.	U_3O_8	0.00059	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The uranium metal cask manufacturing plant is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	U_3O_8	0.05	30	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the uranium metal cask manufacturing plant structure and confinement systems.	U_3O_8	0.05	0.5	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire/explosion/chemical reagent contact inside the cask annulus	The molten uranium within a cask annulus is oxidized, resulting in a fire and/or explosion, but the HEPA filtration system is not affected.	U_3O_8	0.0059	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Uranium metal furnace failure	A large seismic event or beyond-design-basis event causes failure of eight furnaces feeding one cask.	UO_2	35	Puff	Ground

[a] Ground-level releases were assumed to occur outdoors on concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

Notation: HEPA = high-efficiency particulate air; NA = not applicable; UO_2 = uranium dioxide; U_3O_8 = triuranium octaoxide.

TABLE H.6 Estimated Radiological Doses per Accident Occurrence for the Manufacture and Use Options

		Maximum Dose[c]				Minimum Dose[c]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[a]	Frequency Category[b]	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident	L	1.5×10^{-8}	1.3×10^{-7}	1.5×10^{-8}	2.7×10^{-5}	4.5×10^{-12}	3.6×10^{-11}	7.6×10^{-10}	2.7×10^{-7}
Earthquake	U	7.7×10^{-2}	2.9×10^{-2}	2.3×10^{-3}	3.2×10^{-1}	3.2×10^{-3}	1.2×10^{-3}	9.2×10^{-5}	1.1×10^{-3}
Fire/explosion/chemical reagent contact inside the mixers	EU	1.5×10^{-8}	1.2×10^{-7}	1.5×10^{-8}	2.7×10^{-5}	4.4×10^{-12}	3.6×10^{-11}	7.5×10^{-10}	2.7×10^{-7}
Manufacture and Use as Metal Shielding									
Mishandling/drop of drum/billet inside	L	3.9×10^{-8}	3.3×10^{-7}	4.0×10^{-8}	7.0×10^{-5}	1.2×10^{-11}	9.4×10^{-11}	2.0×10^{-9}	7.1×10^{-7}
Earthquake	U	1.1×10^{-2}	4.3×10^{-3}	3.4×10^{-4}	4.6×10^{-2}	4.7×10^{-4}	1.8×10^{-4}	1.3×10^{-5}	1.6×10^{-4}
Fire/explosion/chemical reagent contact inside the cask annulus	EU	1.9×10^{-7}	1.6×10^{-6}	2.0×10^{-7}	3.5×10^{-4}	5.8×10^{-11}	4.7×10^{-10}	9.8×10^{-9}	3.5×10^{-6}
Uranium metal furnace failure	I	2.3×10^{-1}	8.7×10^{-2}	7.0×10^{-3}	1.9	2.3×10^{-1}	8.7×10^{-2}	5.5×10^{-3}	4.2×10^{-2}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($>10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($<10^{-6}$/yr).

[c] Maximium and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

TABLE H.7 Estimated Radiological Health Risks per Accident Occurrence for the Manufacture and Use Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI	Population	MEI	Population	MEI	Population	MEI	Population
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident	L	6×10^{-12}	5×10^{-11}	8×10^{-12}	1×10^{-8}	2×10^{-15}	1×10^{-14}	4×10^{-13}	1×10^{-10}
Earthquake	U	3×10^{-5}	1×10^{-5}	1×10^{-6}	2×10^{-4}	1×10^{-6}	5×10^{-7}	5×10^{-8}	5×10^{-7}
Fire/explosion/chemical reagent contact inside the mixers	EU	6×10^{-12}	5×10^{-11}	8×10^{-12}	1×10^{-8}	2×10^{-15}	1×10^{-14}	4×10^{-13}	1×10^{-10}
Manufacture and Use as Metal Shielding									
Mishandling/drop of drum/billet inside	L	2×10^{-11}	1×10^{-10}	2×10^{-11}	4×10^{-8}	5×10^{-15}	4×10^{-14}	1×10^{-12}	4×10^{-10}
Earthquake	U	4×10^{-6}	2×10^{-6}	2×10^{-7}	2×10^{-5}	2×10^{-7}	7×10^{-8}	7×10^{-9}	8×10^{-8}
Fire/explosion/chemical contact reagent inside the cask annulus	EU	8×10^{-11}	7×10^{-10}	1×10^{-10}	2×10^{-7}	2×10^{-14}	2×10^{-13}	5×10^{-12}	2×10^{-9}
Uranium metal furnace failure	I	9×10^{-5}	3×10^{-5}	4×10^{-6}	1×10^{-3}	9×10^{-5}	3×10^{-5}	3×10^{-6}	2×10^{-5}

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum risks reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

TABLE H.8 Number of Persons with Potential for Adverse Effects from Accidents under the Manufacture and Use Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Number of Persons[d]: Noninvolved Workers MEI[e]	Maximum Number of Persons[d]: Noninvolved Workers Population	Maximum Number of Persons[d]: General Public MEI[e]	Maximum Number of Persons[d]: General Public Population	Minimum Number of Persons[d]: Noninvolved Workers MEI[e]	Minimum Number of Persons[d]: Noninvolved Workers Population	Minimum Number of Persons[d]: General Public MEI[e]	Minimum Number of Persons[d]: General Public Population
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Tornado[f,g]	U	No	0	No/No	0/0	NA	NA	NA	NA
Fire/explosion/chemical reagent contact inside mixers[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Manufacture and Use as Metal Shielding									
Mishandle/drop of drum/billet inside[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Earthquake	U	No	0	No/No	0/0	No	0	No/No	0/0
Fire/explosion/chemical reagent contact inside cask annulus[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Uranium metal furnace failure	I	Yes	4	No/Yes	0/1	Yes[h]	0	No/Yes[h]	0/0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accidents. In general, maximum risks would occur under meteorological conditions of F stability and 1 m/s wind speed, whereas minimum risks would occur under D stability and 4 m/s wind speed. Results for the general public MEI are for rural/urban locations, respectively.

[e] At the MEI location, the determination is either "Yes" or "No" for potential adverse effects to an individual.

[f] These accidents would result in the largest plume sizes, although no people would be affected.

[g] Meteorological conditions for the tornado scenario were considered to be D stability with 20 m/s wind speed. NA = not applicable.

[h] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because generic worker and general public population distributions were used, which did not show receptors at the MEI locations.

TABLE H.9 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under the Manufacture and Use Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Manufacture and Use as Oxide Shielding									
Mixer/melter discharge accident[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Tornado[f,g]	U	No	0	No/No	0/0	NA	NA	NA	NA
For/explosion/chemical reagent contact inside mixers[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Manufacture and Use as Metal Shielding									
Mishandle/drop of drum/billet inside[f]	L	No	0	No/No	0/0	No	0	No/No	0/0
Earthquake[f]	U	No	0	No/No	0/0	No	0	No/No	0/0
Fire/explosion/chemical reagent contact inside cask annulus[f]	EU	No	0	No/No	0/0	No	0	No/No	0/0
Uranium metal furnace failure	I	Yes	2	No/Yes	0/0	No	0	No/Yes[h]	0/0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum values reflect different meteorological conditions at the time of the accidents. In general, maximum risks would occur under meteorological conditions of F stability and 1 m/s wind speed, whereas minimum risks would occur under D stability and 4 m/s wind speed. Results for the general public MEI are for rural/urban locations, respectively.

[e] At the MEI location, the determination is either "Yes" or "No" for potential irreversible adverse effects to an individual.

[f] These accidents would result in the largest plume sizes, although no people would be affected.

[g] Meteorological conditions for the tornado scenario were considered to be D stability with 20 m/s wind speed. NA = not applicable.

[h] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because generic worker and general public population distributions were used, which did not show receptors at the MEI locations.

off-site public represent the impacts if the associated accident was assumed to occur. These results of the chemical impact analysis may be summarized as follows:

- If the accidents identified in Tables H.8 and H.9 did occur, the number of persons in the off-site population with potential for adverse effects would range from 0 to 1, and the number of off-site persons with potential for irreversible adverse effects would range from 0 to 1 (maximums corresponding to failure of the uranium metal furnace).

- If the accidents identified in Tables H.8 and H.9 did occur, the number of noninvolved workers with potential for adverse effects would range from 0 to 4, and the number of nonvinvolved workers with potential for irreversible adverse effects would range from 0 to 2 (maximums corresponding to failure of the uranium metal furnace).

- The impacts for the uranium metal shielding option would be slightly higher than those for uranium oxide applications. However, the overall impacts for the manufacture and use options would be very small compared with other options.

- For the most severe accident (uranium metal furnace failure), the noninvolved worker MEI would experience potential adverse effects and potential irreversible adverse effects, whereas the general public MEI would experience no adverse impacts at the rural site. If an urban site were chosen for this activity, a small number of both the noninvolved worker and the public MEIs could be affected in terms of both health criteria. The reduced impacts to the public MEI compared with the worker MEI were based on dispersion of the chemical release with downwind distance. For the other accidents assessed, neither the worker nor the public MEI would experience adverse effects.

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (20 years, 2009–2028). The results indicated that the maximum risk values would be less than 1 for all accidents.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible adverse effects was estimated. All the bounding case accidents shown in Table H.9 would involve small releases of uranium oxide and potential exposure to uranium compounds. If the accidents occurred, exposures are estimated to result in death for 1% or less of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Thus, for workers and members of the general public experiencing ranges of 0 to 2 and 0 to 1 irreversible adverse effects, respectively, 0 deaths would be expected.

H.3.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries to all manufacturing facility workers from the fabrication of uranium oxide and uranium metal shielding was calculated using industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council (1995). Construction and manufacturing annual fatality and injury rates were used for the construction and operational phases, respectively, of the manufacturing facility lifetime.

Because manufacturing activities would be quite labor-intensive, relatively high injury incidence rates are predicted, with about one fatality expected over the lifetime of facility operations. There is little difference in impacts between the uranium oxide and metal shielding options, although the fatality and incidence rates for the metal option would be slightly higher.

The estimated number of worker fatalities for the uranium oxide shielding option is 0.76 for the construction and operational phases combined (Table H.10). The estimated number of injuries over the lifetime of the uranium oxide facility is about 640.

The estimated number of worker fatalities for the uranium metal shielding option is 0.85 for the construction and operational phases combined (Table H.10). The estimated number of injuries over the lifetime of the metal facility is about 670.

TABLE H.10 Potential Impacts to Human Health from Physical Hazards under Accident Conditions for the Manufacture and Use Options

	Impacts to All Manufacturing Facility Workers[a]			
	Incidence of Fatalities[b]		Incidence of Injuries[b]	
Shielding Option	Construction	Operations	Construction	Operations
Uranium oxide casks	0.38	0.38	140	500
Uranium metal casks	0.48	0.37	180	490

[a] All construction and operational workers at the manufacturing facilities were included in physical hazard risk calculations.

[b] The incidence of fatalities and incidence of injuries were calculated as the number of full-time-equivalent employees times the annual fatality rate times the number of years. Only injuries involving lost workdays were estimated. Injury and fatality incidence rates used in the calculations were taken from National Safety Council (1995).

H.3.3 Air Quality

The methodology used to analyze the air quality impacts from both uranium oxide and uranium metal manufacturing and use options is provided in Appendix C and Tschanz (1997). The pollutant concentrations at several distances from the center of the facility were estimated because of uncertainty regarding the size and location of the generic manufacturing facility. Estimates at 750 m from the center of the manufacturing facilities are comparable to estimates for options based on representative environmental settings (i.e., conversion and long-term storage options using the three current storage sites as representative of those settings).

For both options, by far the largest emissions, and hence impacts on air quality, would occur during construction of the manufacturing facility. Table H.11 presents a comparison of some of the pollutant impacts from construction of the two types of manufacturing facilities at a generic wet environmental setting. The estimated pollutant concentrations — carbon monoxide (CO), nitrogen oxides (NO_x), and PM_{10} (particulate matter with a mean diameter of 10 μm or less) — are all 9% or less of the applicable air quality standards, even at the closest distance from the emissions point. The ranges of impacts for the generic wet setting (as represented by the results in Table H.11) are greater than those estimated for a generic dry setting, and the uncertainties of the wet setting impacts are also greater.

The area source emissions during operation of the manufacturing facility for either option would be smaller than during construction. For both types of facility, operations would emit about 4% as much CO and NO_x and about 1.4% as much PM_{10} as would be emitted during construction. The impacts from these low emissions would be negligible.

The quantities of uranium oxide emitted during operation of either manufacturing facility are estimated to be quite small. The uranium oxide facility would emit only 8 g/yr of uranium as UO_2, which corresponds to an annual average concentration of about 1.6×10^{-7} μg/m^3 at a distance of 3,300 ft (1,000 m). The approximately 50 g/yr of uranium in triuranium octaoxide (U_3O_8) emitted by the uranium metal facility would produce an annual average uranium concentration of 9.9×10^{-7} μg/m^3 at 3,300 ft (1,000 m). Impacts on air quality would be negligible for both options.

No quantitative estimate was made of the impacts of operations on ozone conditions in the atmosphere. Ozone formation is a regional issue that would be affected by emissions for the entire area around a proposed manufacturing site. The pollutants most relevant to ozone formation that would result from the manufacturing options are hydrocarbons (HC) and NO_x. In later Phase II studies, when specific technologies and sites would be selected, the potential effects of these pollutants released from a proposed facility at a specific site could be evaluated relative to the total emissions of HC and NO_x in the surrounding area. Small additional contributions to the total regional emissions would be unlikely to alter the ozone attainment status of the region.

TABLE H.11 Estimated Pollutant Emissions during Construction of a Shielding Manufacturing Facility in a Wet Environmental Setting[a]

	Estimated Maximum Pollutant Emissions[b]							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Option/ Pollutant Distance/ from Source	Range ($\mu g/m^3$)	Fraction of Standard[c]	Range ($\mu g/m^3$)	Fraction of Standard[c]	Range ($\mu g/m^3$)	Fraction of Standard[c]	Range ($\mu g/m^3$)	Fraction of Standard[c]
Uranium oxide								
CO								
750 m	78 – 150	0.0038	13 – 30	0.0030	–	–	–	–
1,000 m	71 –120	0.0030	10 – 23	0.0023	–	–	–	–
1,500 m	58 – 89	0.0022	6.5 – 14	0.0014	–	–	–	–
NO_x								
750 m	–	–	–	–	–	–	3.3 – 8.5	0.085
1,000 m	–	–	–	–	–	–	1.8 – 4.6	0.046
1,500 m	–	–	–	–	–	–	0.60 – 2.2	0.022
PM_{10}								
750 m	–	–	–	–	1.8 – 4.6	0.031	0.25 – 0.61	0.012
1,000 m	–	–	–	–	1.4 – 3.3	0.022	0.13 – 0.33	0.0066
1,500 m	–	–	–	–	0.81 – 2.2	0.015	0.062 – 0.16	0.0032
Uranium metal								
CO								
750 m	83 – 160	0.0040	14 – 32	0.0032	–	–	–	–
1,000 m	76 – 128	0.0032	11 – 24	0.0024	–	–	–	–
1,500 m	62 – 95	0.0024	6.9 – 15	0.0015	–	–	–	–
NO_x								
750 m	–	–	–	–	–	–	3.5 – 9.1	0.091
1,000 m	–	–	–	–	–	–	1.9 – 4.9	0.049
1,500 m	–	–	–	–	–	–	0.64 – 2.3	0.023
PM_{10}								
750 m	–	–	–	–	1.8 – 4.7	0.031	0.26 – 0.62	0.012
1,000 m	–	–	–	–	1.4 – 3.4	0.023	0.13 – 0.34	0.0068
1,500 m	–	–	–	–	0.83 – 2.3	0.015	0.063 – 0.16	0.0032

[a] Results for a generic wet setting bound the results for a generic dry setting.

[b] A hyphen (–) indicates that no standard is available for that averaging period.

[c] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

H.3.4 Water and Soil

The methodology used to determine water and soil impacts is presented in Appendix C and Tomasko (1997).

The environmental resource needs for the manufacturing options are summarized in Table H.12. The resource requirements (in particular, the paved area, volume of excavated material, and water usage) would be greater for the uranium metal option than for the uranium oxide option. Because the manufacture and use option is based on a generic site without a specified location and description, impacts could not be assessed on a site-specific basis; however, the impacts to surface

TABLE H.12 Summary of Environmental Parameters for the Manufacture and Use Options

		Requirements	
Shielding Option	Unit	Construction	Operations[a]
Uranium oxide			
Land area	acres	90	–
Disturbed land	acres	54	–
Building area	acres	14	–
Paved area	acres	15	–
Pond area	acres	2.7	–
Excavated material	yd^3	175,000	–
Hauled material	yd^3	85,500	–
Annual water	million gal/yr	35	7.5
Wastewater	million gal/yr	7.9	4.8
Uranium metal			
Land area	acres	90	–
Disturbed land	acres	54	–
Building area	acres	15	–
Paved area	acres	18	–
Pond area	acres	2.7	–
Excavated material	yd^3	180,000	–
Hauled material	yd^3	88,000	–
Annual water	million gal/yr	43	7.4
Wastewater	million gal/yr	8.5	5.0

[a] A hyphen (–) indicates no environmental resource needs.

water, groundwater, and soil would be smaller for the uranium oxide option because of its smaller resource requirements.

If the manufacture and use facility were located on a site having an area that was large compared with the size of the facility, and if the facility was near a river having a minimum flow that was large compared with annual water use and wastewater discharge, impacts to surface water, groundwater, and soil would be negligible. Negligible impacts would occur because a large site and large river could provide sufficient resource buffering to mitigate the effects produced by construction and operation of the facility.

On the other hand, if the site or the minimum flow in the river were small relative to the resource requirements, impacts would be larger. For example, if the minimum flow in the river was 500 gpm, the net annual water withdrawal would be about 15% of the flow. The impact of this relative withdrawal could produce moderate to large impacts to existing floodplains.

Similarly, if the facility was located in an urban area, paving 18 acres (7 ha) and constructing buildings on another 15 acres (6 ha) could seriously impact the local carrying capacity of storm-water runoff and produce local flooding. In addition, the paving and construction of the facility on a 90-acre (36-ha) site would produce moderate to large impacts to local soil permeability and erosion potential.

No process water effluents would be anticipated from the manufacturing facility (LLNL 1997), so no impacts to surface water quality would be expected. There are no accidents identified in the engineering analysis report (LLNL 1997) that would directly impact surface water. Secondary impacts resulting from deposition of airborne contaminants would not be measurable because of the low concentrations of deposited material.

H.3.5 Socioeconomics

Because the location of a shielding manufacturing facility has not yet been determined, the socioeconomic impacts of the shielding manufacturing options were analyzed on a non-site-specific basis for a generic site. The potential impacts of each facility on direct employment and direct income in the peak year of construction and in first year of operations are shown in Table H.13. Discussion of the assessment methodology is presented in Appendix C and Allison and Folga (1997).

Construction of a UO_2 shielding manufacturing facility would create 160 direct jobs and \$7 million in direct income during the peak year of construction. Operation of the facility would create 470 direct jobs and produce \$33 million in direct income in each year of facility operations.

TABLE H.13 Potential Socioeconomic Impacts from Construction and Operation of the Shielding Manufacturing Facilities

Option/Parameter	Construction[a]	Operations[b]
Manufacture from UO_2		
Direct employment	160	470
Direct income ($ million 1996)	7	33
Manufacture from metal		
Direct employment	190	470
Direct income ($ million 1996)	9	33

[a] Impacts during the peak year of construction, 2007. Preoperations were assumed to occur from 1999 through 2008, with actual construction requiring 7 years.

[b] Impacts are the annual averages for operations for the period 2009 through 2028.

Construction of a metal shielding manufacturing facility would create 190 direct jobs and $9 million in direct income during the peak year of construction. Operation of the facility would create 470 direct jobs and produce $33 million in direct income in each year of facility operations.

H.3.6 Ecology

Moderate adverse impacts to ecological resources could result from construction of a shielding manufacturing facility. Impacts could include mortality of individual organisms, habitat loss, or changes in biotic communities. Impacts due to facility operation would be negligible. Discussion of the methodology used to assess ecological impacts is presented in Appendix C.

H.3.6.1 Uranium Oxide

Site preparation for the construction of a uranium oxide shielding manufacturing facility would require the disturbance of approximately 54 acres (22 ha), including the permanent replacement of approximately 32 acres (13 ha) with structures, paved areas, and a storm-water pond. Existing vegetation would be destroyed during land-clearing activities. The facility would be included within a 90-acre (36-ha) area consisting of buildings, roads, and landscaped areas, which would be maintained as a controlled access area. The specific vegetation communities that would be eliminated by site preparation would depend on the location selected for the facility. The loss of 54 acres (22 ha) of undeveloped land and limited vegetation community development on the remainder of the 90-acre site would constitute a moderate adverse impact to vegetation. Erosion of exposed soil at construction sites could reduce the effectiveness of restoration efforts and create sedimentation downgradient of the site. The implementation of standard erosion control measures, installation of storm-water retention ponds, and immediate replanting of disturbed areas with native species would help minimize impacts to vegetation. Impacts from facility construction are summarized in Table H.14.

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land clearing activities. Mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities, and thus competition for food and nesting sites, would increase in these areas, potentially reducing the survivability or reproductive capacity of displaced individuals. Some wildlife species would be expected to recolonize replanted areas near the manufacturing facility following completion of construction. The permanent loss of 32 to 90 acres (13 to 36 ha) of habitat due to the construction of a facility for manufacture of uranium oxide shielding would be considered a moderate adverse impact to wildlife.

Wetlands could potentially be eliminated or otherwise impacted during construction. Impacts to wetlands and aquatic habitats due to alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur. Unavoidable impacts to wetlands would require a

TABLE H.14 Impacts to Ecological Resources from Construction of the Manufacturing Facility

Option/Resource	Type of Impact	Degree of Impact
Uranium oxide		
Vegetation	Loss of 54 acres	Moderate adverse impact
Wildlife	Loss of 32 to 90 acres	Moderate adverse impact
Wetlands	Potential loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Potential adverse impact
Protected species	Potential destruction, habitat loss	Potential adverse impact
Uranium metal		
Vegetation	Loss of 54 acres	Moderate adverse impact
Wildlife	Loss of 36 to 90 acres	Moderate adverse impact
Wetlands	Potential loss, degradation	Potential adverse impact
Aquatic species	Water quality, habitat reduction	Potential adverse impact
Protected species	Potential destruction, habitat loss	Potential adverse impact

Clean Water Act Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies.

Prior to construction of a manufacturing facility, a survey for state and federally listed threatened, endangered, or candidate species, or species of special concern would be conducted. Impacts to these species could thus be avoided, or, where impacts were unavoidable, mitigation could be developed.

Ecological resources in the vicinity of the manufacturing facility would be exposed to atmospheric emissions from the boiler stack and process stack; however, emission levels would be expected to be extremely low (Section H.3.3). The maximum annual air concentration of UO_2 would be approximately 1.6×10^{-7} $\mu g/m^3$. Consequent impacts to biota would be expected to be negligible.

The manufacturing process would require withdrawal of water from surface waters or groundwater, as well as discharge of wastewater. Depending on the facility location, such withdrawal and discharge could potentially alter water levels (Section H.3.4). The altered water levels could, in turn, impact aquatic ecosystems, including wetlands, especially those located along the periphery of the affected surface water bodies.

Facility accidents, as discussed in Section H.3.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors, such as location of the accident, season, and meteorological conditions.

H.3.6.2 Uranium Metal

The construction of a facility for the manufacture of depleted uranium metal shielding would generally result in the types of impacts associated with the manufacture of uranium oxide shielding. However, site preparation for the construction of a metal shielding manufacturing facility would require the disturbance of approximately 54 acres (22 ha), including the permanent replacement of approximately 36 acres (15 ha) of current land cover with structures, paved areas, and a storm-water pond. The facility would be included within a 90-acre (36-ha) area consisting of buildings, roads, and landscaped areas, which would be maintained as a controlled access area. The loss of 54 acres (22 ha) of undeveloped land and limited vegetation community development on the remainder of the 90-acre (36-ha) site would constitute a moderate adverse impact to vegetation.

The permanent loss of 36 to 90 acres (15 to 36 ha) of habitat would be considered a moderate adverse impact to wildlife. Impacts to ecological resources from operation of the uranium metal manufacturing facility would be similar to those due to operation of the uranium oxide facility.

H.3.7 Waste Management

For both options, the construction and operation of a depleted uranium shielding manufacture facility would generate LLW, hazardous waste, and nonhazardous waste. The LLW would consist of surface contaminated metals; noncombustible, noncompactible solids; dry active wastes; spent high-efficiency particulate air (HEPA) filters; and incinerator ash. Hazardous wastes generated would include paints, thinners, solvents, phenol, mercury (lamps), sulfuric acid, naphtha, lead (batteries), and pesticides.

Because the uranium oxide or uranium metal facility was assumed to be constructed at a generic, uncontaminated site, no radioactive waste would be generated during construction. About 94 and 105 yd^3 (72 and 80 m^3) of hazardous waste would be generated during construction for the uranium oxide and metal shielding facilities, respectively. These wastes would be sent to existing commercial treatment and disposal facilities. Nonhazardous waste generated during construction would be expected to total about 78,000 and 92,000 yd^3 (60,000 and 70,000 m^3), respectively, for the two options.

All radioactive wastes generated during operation of the uranium oxide or uranium metal facility would be routed to the facility waste management station. This part of the facility would include a grouting station and an incinerator. Failed mixers from a uranium oxide facility would be sent directly to disposal; all other facility wastes would be grouted. Spent HEPA filters would be drummed for disposal, and dry active waste would be incinerated, with the resulting ash grouted for disposal. Table H.15 lists expected LLW generation. The annual generation of 165 and 850 yd^3 (126 and 650 m^3) of LLW requiring disposal represents about 600 and 3,200 drums, respectively, per year and would represent about 0.2 and 1% of the projected annual LLW treatment volume for all DOE facilities nationwide (see Appendix C, Section C.10). All of the radioactive waste would be categorized as Class A by the NRC and would be suitable for near-surface disposal. Unlike the uranium oxide option, solidified ash waste from the uranium metal facility might require disposal in a special cell or mine. Hazardous wastes generated during operations are expected to be about 4 times the volume generated during construction. About 275 to 330 tons (250 to 300 metric tons) of nonhazardous waste would be generated annually and would be sent to commercial landfills.

No assumptions were made regarding the fate of the oxide- and metal-shielded casks after use. The empty casks could be recycled, stored, or disposed of as LLW.

TABLE H.15 Summary of Waste Volumes from the Manufacture of Depleted Uranium Shielding

Waste Type	Unit	Waste Volume: Uranium Oxide	Waste Volume: Uranium Metal
Construction[a]			
Hazardous	m^3	71.6	79.5
Nonhazardous	m^3	60,000	70,000
Operations[b]			
Low-level waste	m^3/yr	126	650
Hazardous	m^3/yr	286	318
Nonhazardous	metric tons/yr	250	300

[a] Total volumes generated during the entire 7-year construction period.

[b] Annual volumes generated over normal operating lifetime of 20 years.

H.3.8 Resource Requirements

Resource requirements for the two manufacture and use options are presented in this section. These resource requirements are for the manufacturing of depleted uranium shielding only and do not include resources required for conversion to uranium oxide or uranium metal. Resource requirements for conversion are presented in Appendix F, Section F.3.8.

Estimated utilities and materials required for constructing a shielding manufacturing facility are listed in Table H.16 for the uranium oxide and uranium metal options (LLNL 1997). These required materials and chemicals are readily available and are not considered rare or unique. The total quantities of commonly used construction materials is not expected to be significant. No strategic and critical materials (e.g., Monel or Inconel) are projected to be consumed during construction. Energy resources used during construction would include diesel fuel and gasoline for construction equipment and transportation vehicles. The required electricity would presumably be purchased from commercial utilities.

Energy resources required for operating the two types of shielding manufacturing facilities are shown in Table H.17. No strategic and critical materials (e.g., Monel or Inconel) are projected to be consumed for either construction or operations phases. Energy resources during operations would include the consumption of diesel fuel for operations equipment (including backup electrical generators) and natural gas for space heating. Small amounts of diesel fuel and natural gas are

TABLE H.16 Resource Requirements for Construction of Shielding Manufacturing Facilities

		Requirements	
Utility/Resource	Unit	Uranium Oxide	Uranium Metal
Utilities			
Electricity	MW-yr	4.7	4.9
Solids			
Concrete	yd^3	60,000	62,000
Steel	tons	11,600	12,000
Liquids			
Diesel fuel	million gal	0.61	0.63
Gasoline	million gal	0.2	0.2

Source: LLNL (1997).

TABLE H.17 Resource Requirements for Operation of Shielding Manufacturing Facilities

		Annual Requirement	
Resource	Unit	Uranium Oxide	Uranium Metal
Electricity	MW	3.8	4.7
Diesel fuel	gal	2,000	2,000
Natural gas	million scf	20	32

Source: LLNL (1997).

projected to be used. The required electricity would presumably be purchased from commercial utilities.

H.3.9 Land Use

The assessment of potential land-use impacts for the manufacturing and use options was based on a determination of areal requirements for each option and the potential for incompatibility. The uranium oxide and uranium metal options would result in similar moderate land-use impacts. Both facilities would have a total site requirement of 90 acres (36 ha), of which 54 acres (22 ha) would be disturbed or cleared (LLNL 1997). Although the uranium oxide facility would produce a slightly smaller volume of excavated material than the uranium metal facility, topographical modifications of on-site land could result under both options.

No site has been chosen for a uranium oxide or uranium metal facility, but selection of a site at or near a location that is already dedicated to or zoned for similar use could result in reduced land-use impacts because immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land. Traffic patterns could experience potentially moderate level-of-service impacts from the peak year construction labor force. Any such traffic impacts, however, would be greatly reduced once post-construction operations begin.

H.3.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur if the manufacture and use options considered in this PEIS were implemented include impacts to cultural resources and environmental justice, as well as the visual environment (e.g., aesthetics), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of the manufacturing facilities. These impacts, although considered, were not analyzed in detail for one or more of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier *National Environmental Policy Act* (NEPA) documentation when specific sites are considered;

- Consideration of these impacts would not contribute to differentiation among the alternatives and, therefore, would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

H.4 REFERENCES FOR APPENDIX H

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APPENDIX I:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR DISPOSAL OF OXIDE

CONTENTS (APPENDIX I)

CONTENTS (Cont.)

TABLES

TABLES (Cont.)

TABLES (Cont.)

NOTATION (APPENDIX I)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

BEMR	*The 1996 Baseline Environmental Management Report*
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
HEPA	high-efficiency particulate air (filter)
LCF	latent cancer fatality
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
MCL	maximum contaminant level
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 μm or less
Rf	retardation factor
WM PEIS	*Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*

Chemicals

CO	carbon monoxide
HC	hydrocarbons
NO_x	nitrogen oxides
SO_x	sulfur oxides
UF_6	uranium hexafluoride
UO_2	uranium dioxide
$UO_3 \cdot H_2O$	schoepite (hydrous uranium oxide)
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

cm	centimeter(s)	m	meter(s)
d	day(s)	m^3	cubic meter(s)
ft	foot (feet)	mi^2	square mile(s)
ft^3	cubic foot (feet)	min	minute(s)
g	gram(s)	mrem	millirem(s)
gal	gallon(s)	MWh	megawatt-hour(s)
gpm	gallon(s) per minute	pCi	picocurie(s)
ha	hectare(s)	ppm	part(s) per million
in.	inch(es)	rad	radiation absorbed dose(s)
kg	kilogram(s)	rem	roentgen equivalent man
km	kilometer(s)	s	second(s)
km^2	square kilometer(s)	scf	standard cubic foot (feet)
L	liter(s)	ton(s)	short ton(s)
lb	pound(s)	yd^3	cubic yard(s)
µg	microgram(s)	yr	year(s)
µm	micrometer(s)		

APPENDIX I:

ENVIRONMENTAL IMPACTS OF OPTIONS FOR DISPOSAL OF OXIDE

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing the disposal options considered in the PEIS. The discussion provides background information for these options, as well as a summary of the estimated environmental impacts associated with each option.

> **Disposal Options**
>
> Depleted uranium material would be disposed of as low-level radioactive waste. The disposal options assessed in the PEIS were defined on the basis of the chemical form of the uranium and the type of disposal facility. The following disposal options were considered:
>
> **Disposal as U_3O_8.** Depleted uranium could be disposed of as U_3O_8, either ungrouted (bulk) or grouted U_3O_8, following conversion. The disposal facilities considered included shallow earthen structures, belowground vaults, and an underground mine.
>
> **Disposal as UO_2.** Similar to U_3O_8, depleted uranium could be disposed of as UO_2 following conversion, either in ungrouted or grouted form. The disposal facilities considered were the same as those considered for U_3O_8: shallow earthen structures, belowground vaults, and an underground mine.

Disposal is defined as the emplacement of material in a manner designed to ensure its isolation for the foreseeable future. For the PEIS disposal options, depleted uranium was assumed to be disposed of belowground as low-level radioactive waste beginning in 2009. Compared with long-term storage, disposal is considered permanent, with no intent to retrieve the material for future use. In fact, considerable and deliberate effort would be required to regain access to the material following disposal. Low-level radioactive waste disposal in burial facilities has been practiced in the United States for over 50 years.

The disposal options considered in the PEIS are defined by the chemical form of the depleted uranium to be disposed of and by the type of disposal facility. Two chemical forms of uranium oxides were evaluated: triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2). These forms were considered because of their chemical stability; UF_6 and uranium metal are not considered acceptable forms because they are chemically reactive (Lawrence Livermore National Laboratory [LLNL] 1997). Three types of disposal facilities were considered for each chemical form: (1) shallow earthen structures (engineered "trenches"), (2) vaults, and (3) an underground mine. The chemical forms and disposal options are summarized in Table I.1. Each type of disposal facility is described in Section I.2.

For each of the uranium oxides, two physical waste forms were considered in the PEIS, ungrouted and grouted. Ungrouted waste refers to U_3O_8 or UO_2 in the powder or pellet form produced during the conversion process. This bulk material would be disposed of in either 55-gal (208-L) drums for U_3O_8 or 30-gal (110-L) drums for UO_2. Grouted waste refers to the solid material obtained by mixing the uranium oxides with cement and repackaging it in drums. Grouting is intended to increase structural strength and stability of the waste, and reduce the leaching rate of the waste in water. However, because cement is added to the uranium oxide, grouting would increase the total volume requiring disposal. Grouting of waste was assumed to occur at the disposal facility.

In general, disposal facilities would be stand-alone, single-purpose facilities consisting of a central receiving building/warehouse (called the wasteform facility) and several disposal units. Depending on the option, the disposal units would be a series of shallow earthen structures, vaults, or underground mine tunnels (called drifts). Activities at the disposal facility would include receipt of containers of depleted uranium oxide by truck or railcar, inspection of the containers, grouting the material if necessary, and placement of the containers into the disposal units. The disposal unit would then be backfilled with soil, sand, gravel, or other material and covered with multiple layers of natural material (such as clay) designed to minimize infiltration of water for long periods of time. The disposal facilities would be designed to protect the waste from the environment and prevent potential releases of material to the environment. Following disposal of the last containers, the disposal facility would be closed and then monitored and maintained for a period of time consistent with regulatory and license requirements.

The potential environmental impacts from the disposal options were evaluated on the basis of information provided in the engineering analysis report (LLNL 1997). For each disposal option, the engineering analysis report provides preconceptual facility design data, including descriptions of facility layouts, resource requirements, estimates of effluents, wastes, and emissions, and

TABLE I.1 Summary of Depleted Uranium Chemical Forms and Disposal Options Considered

Physical/ Chemical Form	Disposal Option Considered: Shallow Earthen Structure	Vault	Mine
Grouted U_3O_8	Yes	Yes	Yes
Ungrouted U_3O_8	Yes	Yes	Yes
Grouted UO_2	Yes	Yes	Yes
Ungrouted UO_2	Yes	Yes	Yes

descriptions of potential accident scenarios. This report also contains additional discussion of issues related to low-level radioactive waste (LLW) disposal and discusses the results of previous assessments of the long-term impacts of uranium disposal.

The potential environmental impacts from disposal would differ from those for the other options considered in the PEIS. Whereas the impacts from the other options would generally occur during the operational period of the facilities considered (40 years or less), the impacts from disposal might occur hundreds to thousands of years after the facility had ceased operating. Thus, disposal impacts were estimated for two phases: (1) the operational phase, which includes construction of the facility and the period in which waste would be actively placed into disposal units, and (2) the post-closure phase, which considers hundreds of years in the future, beyond the time that any engineered disposal facilities would be expected to function as designed. The environmental impacts for the operational phase are presented in Section I.3, and those for the post-closure phase are presented in Section I.4.

Potential impacts during the operational phase, which would include construction activities and the handling of waste containers as they were placed into disposal units, would primarily affect workers. In addition, some potential impacts to the public would occur from air emissions during grouting of the waste. The potential impacts during the post-closure phase would affect only the public and would follow the eventual release of material from the disposal facility to the environment. For assessment purposes, all disposal facilities were assumed to fail, or release waste to the environment, at the end of an institutional control period (failure was assumed to occur around the year 2140, 100 years after site closure). Because of the infiltration of water, uranium would ultimately migrate through the soil, eventually contaminating the groundwater and potentially exposing members of the public. Post-closure impacts were estimated at 1,000 years after the disposal facilities were assumed to fail.

The potential environmental impacts from the disposal options were not determined on a site-specific basis because the location of a disposal facility would not be decided until sometime in the future. Instead, for assessment purposes, two generic environmental settings were defined, a generic dry setting and a generic wet setting. The conditions of the dry setting would be typical of a site in the arid western United States, and the conditions of the wet setting would be typical of a site in the eastern United States.

The estimated impacts associated with the disposal options are subject to a great deal of uncertainty, especially for the post-closure period. The degree of uncertainty in the disposal impacts is greater than that for the other categories of options in the PEIS, because disposal impacts consider an extremely long period of time and depend on predicting the behavior of the waste material as it interacts with soil and water in a complex and changing environment. Consequently, the estimated disposal impacts are very dependent on the assumptions made for the assessment, including such key factors as soil characteristics, water infiltration rates, depth to underlying groundwater table, chemistry of different uranium compounds, and locations of future human receptors. These factors could vary widely depending on site-specific conditions. Therefore, a range of these factors was selected for analysis to represent the range of actual conditions that could occur.

I.1 SUMMARY OF DISPOSAL OPTION IMPACTS

This section provides a summary of the potential environmental impacts associated with the disposal of depleted uranium oxides in shallow earthen structures, vaults, and a mine during two distinct phases: (1) the operational phase and (2) the post-closure phase. Analysis of the operational phase included facility construction and the time during which waste would be actively placed in disposal units (2009 through 2028). Analysis of the post-closure phase considered potential impacts 1,000 years after the disposal units fail (i.e., release uranium material to the environment). For each phase, impacts were estimated for both generic wet and dry environmental settings. Additional discussion and details related to the assessment methodologies and results for each area of impact are provided in Section I.3 for the operational phase and Section I.4 for the post-closure phase.

For the operational phase, the potential environmental impacts for disposal of U_3O_8 and UO_2 are summarized in Tables I.2 and I.3, respectively. Within each table, the potential impacts are presented first for the grouted form and then for the ungrouted form. The following is a general summary of potential environmental impacts during the operational phase:

- ***Potential Adverse Impacts.*** Potential adverse impacts during the operational phase would be small and generally similar for all options. Minor to moderate impacts would occur during construction activities, although these impacts would be temporary and easily mitigated by common engineering and construction practices. Impacts during waste emplacement activities also would be small and limited to involved and noninvolved workers.

- ***Wet or Dry Environmental Setting.*** In general, potential impacts would be similar for generic wet and dry environmental settings during the operational phase.

- ***U_3O_8 or UO_2.*** The potential disposal impacts tend to be slightly larger for U_3O_8 than for UO_2 because the volume of U_3O_8 would be greater and most environmental impacts tend to be proportional to the volume.

- ***Grouted or Ungrouted Waste.*** For both U_3O_8 and UO_2, the disposal of grouted waste would result in larger impacts than disposal of ungrouted waste during the operational phase for two reasons: (1) grouting increases the volume of waste requiring disposal (by about 50%) and (2) grouting operations result in small emissions of uranium material to the air and water.

TABLE I.2 Summary of Disposal Option Impacts for U_3O_8 during the Operational Phase[a]

A. Grouted

Impacts from Disposal as Grouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Grouted U_3O_8 in Vaults	Impacts from Disposal as Grouted U_3O_8 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers:	**Involved Workers:**	**Involved Workers:**
Total collective dose: 480 person-rem	Total collective dose: 520 person-rem	Total collective dose: 720 person-rem
Total number of LCFs: 0.2 LCF	Total number of LCFs: 0.2 LCF	Total number of LCFs: 0.3 LCF
Noninvolved Workers:	**Noninvolved Workers:**	**Noninvolved Workers:**
Annual dose to MEI : 0.0021 – 0.0088 mrem/yr	Annual dose to MEI : 0.0021 – 0.0088 mrem/yr	Annual dose to MEI : 0.00084 – 0.0085 mrem/yr
Annual cancer risk to MEI: $8 \times 10^{-10} – 4 \times 10^{-9}$ per year	Annual cancer risk to MEI: $8 \times 10^{-10} – 4 \times 10^{-9}$ per year	Annual cancer risk to MEI: $3 \times 10^{-10} – 3 \times 10^{-9}$ per year
Total collective dose: 0.00054 – 0.0035 person-rem	Total collective dose: 0.00059 – 0.0038 person-rem	Total collective dose: 0.00057 – 0.0036 person-rem
Total number of LCFs: $2 \times 10^{-7} – 1 \times 10^{-6}$ LCF	Total number of LCFs: $2 \times 10^{-7} – 2 \times 10^{-6}$ LCF	Total number of LCFs: $2 \times 10^{-7} – 1 \times 10^{-6}$ LCF
General Public:	**General Public:**	**General Public:**
Annual dose to MEI: 0.0061 – 0.026 mrem/yr	Annual dose to MEI: 0.0060 – 0.020 mrem/yr	Annual dose to MEI: 0.0061 – 0.026 mrem/yr
Annual cancer risk to MEI: $3 \times 10^{-9} – 1 \times 10^{-8}$ per year	Annual cancer risk to MEI: $3 \times 10^{-9} – 1 \times 10^{-8}$ per year	Annual cancer risk to MEI: $3 \times 10^{-9} – 1 \times 10^{-8}$ per year
Total collective dose to population within 50 miles: 0.037 – 0.11 person-rem	Total collective dose to population within 50 miles: 0.037 – 0.11 person-rem	Total collective dose to population within 50 miles: 0.037 – 0.11 person-rem
Total number of LCFs in population within 50 miles: $2 \times 10^{-5} – 6 \times 10^{-5}$ LCF	Total number of LCFs in population within 50 miles: $2 \times 10^{-5} – 6 \times 10^{-5}$ LCF	Total number of LCFs in population within 50 miles: $2 \times 10^{-5} – 6 \times 10^{-5}$ LCF
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE I.2 (Cont.)

Impacts from Disposal as Grouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Grouted U_3O_8 in Vaults	Impacts from Disposal as Grouted U_3O_8 in a Mine
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 140 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 140 rem	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 140 rem
Risk of LCF to MEI: 0.06	Risk of LCF to MEI: 0.06	Risk of LCF to MEI: 0.06
Collective dose: 6.1 person-rem	Collective dose: 6.1 person-rem	Collective dose: 6.1 person-rem
Number of LCFs: 0.002	Number of LCFs: 0.002	Number of LCFs: 0.002
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 1.1 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 1.1 rem	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 1.1 rem
Risk of LCF to MEI: 5×10^{-4}	Risk of LCF to MEI: 5×10^{-4}	Risk of LCF to MEI: 5×10^{-4}
Collective dose to population within 50 miles: 1.5 person-rem	Collective dose to population within 50 miles: 1.5 person-rem	Collective dose to population within 50 miles: 1.5 person-rem
Number of LCFs in population within 50 miles: 0.0007 LCF	Number of LCFs in population within 50 miles: 0.0007 LCF	Number of LCFs in population within 50 miles: 0.0007 LCF
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 1 person	Number of persons with potential for adverse effects: 1 person	Number of persons with potential for adverse effects: 1 person
Number of persons with potential for irreversible adverse effects: 1 person	Number of persons with potential for irreversible adverse effects: 1 person	Number of persons with potential for irreversible adverse effects: 1 person
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons

TABLE I.2 (Cont.)

Impacts from Disposal as Grouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Grouted U_3O_8 in Vaults	Impacts from Disposal as Grouted U_3O_8 in a Mine
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.26) fatality, approximately 210 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.44) fatality, approximately 300 injuries	**Construction and Operations:** **All Workers** Approximately 1 fatality, approximately 450 injuries
	Air Quality	
Construction: Annual NO_x concentration potentially as large as 3% of standard; other criteria pollutant concentrations between 0.2 and 2% of respective standards	**Construction:** Annual NO_x concentration potentially as large as 13% of standard; other criteria pollutant concentration between 0.3 and 4% of respective standards	**Construction:** All pollutant concentrations below 0.1% of respective standards
Operations: Annual NO_x concentration potentially as large as 7% of standard; other criteria pollutant concentrations between 0.3 and 3% of respective standards	**Operations:** Annual NO_x concentration potentially as large as 37% of standard; other criteria pollutant concentrations between 0.8 and 10% of respective standards	**Operations:** All pollutant concentrations below 0.02% of respective standards
	Water [b]	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
	Soil [b]	
Construction: Negligible, but temporary, impacts	**Construction:** Moderate to large, but temporary, impacts	**Construction:** Moderate to large, but temporary, impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Construction: Potential moderate impacts on employment and income	**Construction:** Potential moderate impacts on employment and income	**Construction:** Potential moderate impacts on employment and income
Operations: Potential moderate impacts on employment and income	**Operations:** Potential moderate impacts on employment and income	**Operations:** Potential moderate impacts on employment and income

TABLE I.2 (Cont.)

Impacts from Disposal as Grouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Grouted U_3O_8 in Vaults	Impacts from Disposal as Grouted U_3O_8 in a Mine
	Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential large impacts to vegetation and wildlife	**Construction:** Potential large impacts to vegetation and wildlife
Operations: Potential adverse impacts to aquatic biota	**Operations:** Potential adverse impacts to aquatic biota	**Operations:** Potential adverse impacts to aquatic biota
	Waste Management	
Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements on the local or national scale are expected; impacts of electrical requirements for mine excavation depend on site location
	Land Use	
Use of approximately 85 acres; potential moderate impacts	Use of approximately 149 acres; potential moderate impacts	Use of approximately 471 acres; potential large impacts, including impacts from disposal of excavated material and potential off-site traffic impacts during construction

B. Ungrouted

Impacts from Disposal as Ungrouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted U_3O_8 in Vaults	Impacts from Disposal as Ungrouted U_3O_8 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 280 person-rem	**Involved Workers:** Total collective dose: 300 person-rem	**Involved Workers:** Total collective dose: 360 person-rem
Total number of LCFs: 0.1 LCF	Total number of LCFs: 0.1 LCF	Total number of LCFs: 0.1 LCF
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE I.2 (Cont.)

Impacts from Disposal as Ungrouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted U_3O_8 in Vaults	Impacts from Disposal as Ungrouted U_3O_8 in a Mine
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 130 rem Risk of LCF to MEI: 0.05 Collective dose: 5.6 person-rem Number of LCFs: 0.002	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 130 rem Risk of LCF to MEI: 0.05 Collective dose: 5.6 person-rem Number of LCFs: 0.002	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 130 rem Risk of LCF to MEI: 0.05 Collective dose: 5.6 person-rem Number of LCFs: 0.002
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 1 rem Risk of LCF to MEI: 5×10^{-4} Collective dose to population within 50 miles: 1.3 person-rem Number of LCFs in population within 50 miles: 0.0007 LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 1 rem Risk of LCF to MEI: 5×10^{-4} Collective dose to population within 50 miles: 1.3 person-rem Number of LCFs in population within 50 miles: 0.0007 LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 1 rem Risk of LCF to MEI: 5×10^{-4} Collective dose to population within 50 miles: 1.3 person-rem Number of LCFs in population within 50 miles: 0.0007 LCF
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 1 person Number of persons with potential for irreversible adverse effects: 1 person	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 1 person Number of persons with potential for irreversible adverse effects: 1 person	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 1 person Number of persons with potential for irreversible adverse effects: 1 person
General Public: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons

TABLE I.2 (Cont.)

Impacts from Disposal as Ungrouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted U_3O_8 in Vaults	Impacts from Disposal as Ungrouted U_3O_8 in a Mine
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.13) fatality, approximately 90 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.22) fatality, approximately 140 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.53) fatality, approximately 240 injuries
	Air Quality	
Construction: Annual NO_x concentration potentially as large as 1.3% of standard; all other criteria pollutant concentrations between 0.07 and 0.6% of respective standards	**Construction:** Annual NO_x concentration potentially as large as 3.5% of standard; all other criteria pollutant concentrations between 0.1 and 1% of respective standards	**Construction:** All pollutant concentrations below 0.1% of respective standards
Operations: Annual NO_x concentration potentially as large as 2.3% of standard; all other criteria pollutant concentrations between 0.1 and 1% of respective standards	**Operations:** Annual NO_x concentration potentially as large as 10% of standard; all other criteria pollutant concentrations between 0.3 and 3% of respective standards	**Operations:** All pollutant concentrations below 0.02% of respective standards
	Water[b]	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
	Soil[b]	
Construction: Negligible, but temporary, impacts	**Construction:** Moderate to large, but temporary, impacts	**Construction:** Moderate to large, but temporary, impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Construction: Potential moderate impacts on employment and income	**Construction:** Potential moderate impacts on employment and income	**Construction:** Potential moderate impacts on employment and income
Operations: Potential moderate impacts on employment and income	**Operations:** Potential moderate impacts on employment and income	**Operations:** Potential moderate impacts on employment and income

TABLE I.2 (Cont.)

Impacts from Disposal as Ungrouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted U_3O_8 in Vaults	Impacts from Disposal as Ungrouted U_3O_8 in a Mine
	Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife	**Construction:** Potential large impacts to vegetation and wildlife
Operations: Negligible impacts	**Operations:** Negligible impacts	**Operations:** Negligible impacts
	Waste Management	
Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements on the local or national scale are expected; impacts of electrical requirements for mine excavation depend on site location
	Land Use	
Use of approximately 46 acres; negligible impacts	Use of approximately 75 acres; potential moderate impacts	Use of approximately 232 acres; potential large impacts, including impacts from disposal of excavated material and potential off-site traffic impacts during construction

[a] Impacts presented in the table are for a generic wet setting (typical of the eastern United States). Potential impacts during the operational phase would be similar for a generic dry setting (typical of the western United States).

[b] Impacts are based on a site that would be large compared to the area of the facility, with a nearby river having a minimum flow that would be large compared to water use and discharge requirements.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; NO_x = nitrogen oxides; ROI = region of influence.

TABLE I.3 Summary of Disposal Option Impacts for UO_2 during the Operational Phase[a]

A. Grouted

Impacts from Disposal as Grouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Grouted UO_2 in Vaults	Impacts from Disposal as Grouted UO_2 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 420 person-rem	**Involved Workers:** Total collective dose: 440 person-rem	**Involved Workers:** Total collective dose: 480 person-rem
Total number of LCFs: 0.2 LCF	Total number of LCFs: 0.2 LCF	Total number of LCFs: 0.2 LCF
Noninvolved Workers: Annual dose to MEI: 0.0032 – 0.017 mrem/yr	**Noninvolved Workers:** Annual dose to MEI: 0.0037 – 0.017 mrem/yr	**Noninvolved Workers:** Annual dose to MEI: 0.0016 – 0.016 mrem/yr
Annual cancer risk to MEI: $1 \times 10^{-9} - 7 \times 10^{-9}$ per year	Annual cancer risk to MEI: $1 \times 10^{-9} - 7 \times 10^{-9}$ per year	Annual cancer risk to MEI: $6 \times 10^{-10} - 6 \times 10^{-9}$ per year
Total collective dose: 0.00055 – 0.0036 person-rem	Total collective dose: 0.00061 – 0.0040 person-rem	Total collective dose: 0.00055 – 0.0036 person-rem
Total number of LCFs: $2 \times 10^{-7} - 1 \times 10^{-6}$ LCF	Total number of LCFs: $2 \times 10^{-7} - 2 \times 10^{-6}$ LCF	Total number of LCFs: $2 \times 10^{-7} - 1 \times 10^{-6}$ LCF
General Public: Annual dose to MEI: 0.012 – 0.050 mrem/yr	**General Public:** Annual dose to MEI: 0.012 – 0.050 mrem/yr	**General Public:** Annual dose to MEI: 0.012 – 0.050 mrem/yr
Annual cancer risk to MEI: $6 \times 10^{-9} - 2 \times 10^{-8}$ per year	Annual cancer risk to MEI: $6 \times 10^{-9} - 2 \times 10^{-8}$ per year	Annual cancer risk to MEI: $6 \times 10^{-9} - 2 \times 10^{-8}$ per year
Total collective dose to population within 50 miles: 0.071 – 0.21 person-rem	Total collective dose to population within 50 miles: 0.071 – 0.21 person-rem	Total collective dose to population within 50 miles: 0.071 – 0.21 person-rem
Total number of LCFs in population within 50 miles: $4 \times 10^{-5} - 1 \times 10^{-4}$ LCF	Total number of LCFs in population within 50 miles: $4 \times 10^{-5} - 1 \times 10^{-4}$ LCF	Total number of LCFs in population within 50 miles: $4 \times 10^{-5} - 1 \times 10^{-4}$ LCF
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE I.3 (Cont.)

Impacts from Disposal as Grouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Grouted UO_2 in Vaults	Impacts from Disposal as Grouted UO_2 in a Mine
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Dose to MEI: 0.27 rem	Dose to MEI: 0.27 rem	Dose to MEI: 0.27 rem
Risk of LCF to MEI: 1×10^{-4}	Risk of LCF to MEI: 1×10^{-4}	Risk of LCF to MEI: 1×10^{-4}
Collective dose: 0.011 person-rem	Collective dose: 0.011 person-rem	Collective dose: 0.011 person-rem
Number of LCFs: 5×10^{-6}	Number of LCFs: 5×10^{-6}	Number of LCFs: 5×10^{-6}
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Dose to MEI: 0.0021 rem	Dose to MEI: 0.0021 rem	Dose to MEI: 0.0021 rem
Risk of LCF to MEI: 1×10^{-6}	Risk of LCF to MEI: 1×10^{-6}	Risk of LCF to MEI: 1×10^{-6}
Collective dose to population within 50 miles: 0.0027 person-rem	Collective dose to population within 50 miles: 0.0027 person-rem	Collective dose to population within 50 miles: 0.0027 person-rem
Number of LCFs in population within 50 miles: 1×10^{-6} LCF	Number of LCFs in population within 50 miles: 1×10^{-6} LCF	Number of LCFs in population within 50 miles: 1×10^{-6} LCF
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years	Bounding accident frequency: 1 in 100 years to 1 in 10,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):	**Noninvolved Workers:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons
General Public: Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):	**General Public:** Bounding accident consequences (per occurrence):
Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons	Number of persons with potential for adverse effects: 0 persons
Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons	Number of persons with potential for irreversible adverse effects: 0 persons

TABLE I.3 (Cont.)

Impacts from Disposal as Grouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Grouted UO_2 in Vaults	Impacts from Disposal as Grouted UO_2 in a Mine
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.23) fatality, approximately 180 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.26) fatality, approximately 190 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.50) fatality, approximately 280 injuries
	Air Quality	
Construction: Annual NO_x concentration potentially as large as 0.9% of standard; all other criteria pollutant concentrations between 0.05 and 0.6% of respective standards	**Construction:** Annual NO_x concentration potentially as large as 1% of standard; all other criteria pollutant concentrations between 0.04 and 0.4% of respective standards	**Construction:** All pollutant concentrations less than 10% of concentrations from shallow earthen structure construction
Operations: Annual NO_x concentration potentially as large as 1.8% of standard; all other criteria pollutant concentrations between 0.1 and 1.1% of respective standards	**Operations:** Annual NO_x concentration potentially as large as 5.6% of standard; all other criteria pollutant concentrations between 0.2 and 2% of respective standards	**Operations:** All pollutant concentrations about 10% of those from mine construction
	Water[b]	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
	Soil[b]	
Construction: Negligible, but temporary, impacts	***Construction:*** Moderate to large, but temporary, impacts	***Construction:*** Moderate to large, but temporary, impacts
Operations: No impacts	***Operations:*** No impacts	***Operations:*** No impacts
	Socioeconomics	
Construction: Potential moderate impacts on employment and income	**Construction:** Potential moderate impacts on employment and income	**Construction:** Potential moderate impacts on employment and income
Operations: Potential moderate impacts on employment and income	**Operations:** Potential moderate impacts on employment and income	**Operations:** Potential moderate impacts on employment and income

TABLE I.3 (Cont.)

Impacts from Disposal as Grouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Grouted UO_2 in Vaults	Impacts from Disposal as Grouted UO_2 in a Mine
	Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife	**Construction:** Potential large impacts to vegetation and wildlife
Operations: Potential adverse impacts to aquatic biota	**Operations:** Potential adverse impacts to aquatic biota	**Operations:** Potential adverse impacts to aquatic biota
	Waste Management	
Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements on the local or national scale are expected; impacts of electrical requirements for mine excavation depend on site location
	Land Use	
Use of approximately 39 acres; negligible impacts	Use of approximately 41 acres; negligible impacts	Use of approximately 149 acres; potential moderate impacts, including impacts from disposal of excavated material and potential off-site traffic impacts during construction

B. Ungrouted

Impacts from Disposal as Ungrouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted UO_2 in Vaults	Impacts from Disposal as Ungrouted UO_2 in a Mine
	Human Health – Normal Operations: Radiological	
Involved Workers: Total collective dose: 170 person-rem	**Involved Workers:** Total collective dose: 220 person-rem	**Involved Workers:** Total collective dose: 240 person-rem
Total number of LCFs: 0.07 LCF	Total number of LCFs: 0.09 LCF	Total number of LCFs: 0.09 LCF
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts
	Human Health – Normal Operations: Chemical	
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts

TABLE I.3 (Cont.)

Impacts from Disposal as Ungrouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted UO_2 in Vaults	Impacts from Disposal as Ungrouted UO_2 in a Mine
	Human Health – Accidents: Radiological	
Bounding accident frequency: 1 in 100 years to 1 in 100,000 years	Bounding accident frequency: 1 in 100 years to 1 in 100,000 years	Bounding accident frequency: 1 in 100 years to 1 in 100,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.22 rem Risk of LCF to MEI: 9×10^{-5} Collective dose: 12 person-rem Number of LCFs: 0.005	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.22 rem Risk of LCF to MEI: 9×10^{-5} Collective dose: 12 person-rem Number of LCFs: 0.005	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.22 rem Risk of LCF to MEI: 9×10^{-5} Collective dose: 12 person-rem Number of LCFs: 0.005
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.0017 rem Risk of LCF to MEI: 8×10^{-7} Collective dose to population within 50 miles: 0.046 person-rem Number of LCFs in population within 50 miles: 2×10^{-5} LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.0017 rem Risk of LCF to MEI: 8×10^{-7} Collective dose to population within 50 miles: 0.046 person-rem Number of LCFs in population within 50 miles: 2×10^{-5} LCF	**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.0017 rem Risk of LCF to MEI: 8×10^{-7} Collective dose to population within 50 miles: 0.046 person-rem Number of LCFs in population within 50 miles: 2×10^{-5} LCF
	Human Health – Accidents: Chemical	
Bounding accident frequency: 1 in 100 years to 1 in 100,000 years	Bounding accident frequency: 1 in 100 years to 1 in 100,000 years	Bounding accident frequency: 1 in 100 years to 1 in 100,000 years
Noninvolved Workers: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**Noninvolved Workers:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons
General Public: Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons	**General Public:** Bounding accident consequences (per occurrence): Number of persons with potential for adverse effects: 0 persons Number of persons with potential for irreversible adverse effects: 0 persons

TABLE I.3 (Cont.)

Impacts from Disposal as Ungrouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted UO_2 in Vaults	Impacts from Disposal as Ungrouted UO_2 in a Mine
	Human Health — Accidents: Physical Hazards	
Construction and Operations: **All Workers:** Less than 1 (0.13) fatality, approximately 90 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.15) fatality, approximately 110 injuries	**Construction and Operations:** **All Workers:** Less than 1 (0.33) fatality, approximately 170 injuries
	Air Quality	
Construction: Annual NO_x concentration potentially as large as 0.6% of standard; all other criteria pollutant concentrations between 0.04 and 0.4% of respective standards	**Construction:** Annual NO_x concentration potentially as large as 0.6% of standard; all other criteria pollutant concentrations between 0.03 and 0.3% of respective standards	**Construction:** All pollutant concentrations less than 10% of concentration from shallow earthen structure construction
Operations: Annual NO_x concentration potentially as large as 1.3% of standard; all other criteria pollutant concentrations between 0.08 and 0.8% of respective standards	**Operations:** Annual NO_x concentration potentially as large as 3.3% of standard; all other criteria pollutant concentrations between 0.1 and 1.3% of respective standards	**Operations:** All pollutant concentrations about 10% of those from mine construction
	Water[b]	
Construction: Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater	**Construction:** Negligible impacts to surface water and groundwater
Operations: None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater	**Operations:** None to negligible impacts to surface water and groundwater
	Soil[b]	
Construction: Negligible, but temporary, impacts	**Construction:** Moderate to large, but temporary, impacts	**Construction:** Moderate to large, but temporary, impacts
Operations: No impacts	**Operations:** No impacts	**Operations:** No impacts
	Socioeconomics	
Potential moderate impacts on employment and income	Potential moderate impacts on employment and income	Potential moderate impacts on employment and income
	Ecology	
Construction: Potential moderate impacts to vegetation and wildlife	**Construction:** Potential moderate impacts to vegetation and wildlife	**Construction:** Potential large impacts to vegetation and wildlife
Operations: Negligible impacts	**Operations:** Negligible impacts	**Operations:** Negligible impacts

TABLE I.3 (Cont.)

Impacts from Disposal as Ungrouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted UO_2 in Vaults	Impacts from Disposal as Ungrouted UO_2 in a Mine
	Waste Management	
Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations	Negligible to low impacts on national waste management operations
	Resource Requirements	
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No impacts from resource requirements on the local or national scale are expected; impacts of electrical requirements for mine excavation depend on site location
	Land Use	
Use of approximately 28 acres; negligible impacts	Use of approximately 28 acres; negligible impacts	Use of approximately 102 acres; potential moderate impacts, including impacts from disposal of excavated material and potential off-site traffic impacts during construction

[a] Impacts presented in the table are for a generic wet setting (typical of the eastern United States). Potential impacts during the operational phase would be similar for a generic dry setting (typical of the western United States).

[b] Impacts are based on a site that would be large compared to the area of the facility, with a nearby river having a minimum flow that would be large compared to water use and discharge requirements.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual; NO_x = nitrogen oxides; ROI = region of influence.

- ***Shallow Earthen Structure, Vault, or Mine.*** The potential impacts are essentially similar for disposal in a shallow earthen structure, vault, or mine. However, disposal in a mine could create slightly larger potential impacts if excavation of the mine was required (use of an existing mine would minimize impacts).

For the post-closure phase, the potential environmental impacts for disposal of U_3O_8 and UO_2 are summarized in Tables I.4 and I.5, respectively. Impacts were calculated for a post-failure time of 1,000 years. The potential impacts estimated for the post-closure phase are subject to a great deal of uncertainty because of the extremely long time period considered and the dependence of predictions on the behavior of the waste material as it interacts with soil and water in a distant future environment. The post-closure impacts would depend greatly on the specific disposal facility design and site-specific characteristics. Because of these uncertainties, the assessment assumptions are generally selected to produce conservative estimates of impact, that is, they tend to overestimate the expected impact. Changes in key disposal assumptions could yield significantly different results (see Section I.4).

The following is presented as a general summary of potential environmental impacts during the post-closure phase (from information in Tables I.4 and I.5 and Section I.4):

- ***Potential Adverse Impacts.*** For all disposal options, potentially large impacts to human health and groundwater quality could occur within 1,000 years after failure of a facility in a wet setting, whereas essentially no impacts would occur for a dry setting in the same time frame. Potential impacts would result primarily from the contamination of groundwater. The maximum dose to an individual assumed to live at the edge of the disposal site and use the contaminated water was estimated to be about 110 mrem/yr, which would exceed the 25-mrem/yr limit specified in 10 *Code of Federal Regulations* [CFR] Part 61 and DOE Order 5820.2A. (For comparison, the average dose to an individual from background radiation is about 360 mrem/yr.) Possible exposures (on the order of 10 rem/yr) could occur for shallow earthen structures and vaults if the cover material were to erode and expose the uranium material; however, this would not occur until several thousand years later, and the exposure could be eliminated by adding new cover material to the top of the waste area.

- ***Wet or Dry Environmental Setting.*** The potential impacts would be significantly greater in a wet setting than a dry setting. Essentially no impacts would be expected in a dry setting for more than 1,000 years because of the low water infiltration rate and greater depth to the water table.

TABLE I.4 Summary of Disposal Option Impacts for U_3O_8 during the Post-Closure Phase[a,b]

A. Grouted

Impacts from Disposal as Grouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Grouted U_3O_8 in Vaults	Impacts from Disposal as Grouted U_3O_8 in a Mine
	Human Health: Radiological	
General Public: Annual dose to MEI: 49 – 72 mrem/yr	**General Public:** Annual dose to MEI: 57 – 84 mrem/yr	**General Public:** Annual dose to MEI: 1 – 110 mrem/yr
Annual cancer risk to MEI: $2 \times 10^{-5} - 4 \times 10^{-5}$ per year	Annual cancer risk to MEI: $3 \times 10^{-5} - 4 \times 10^{-4}$ per year	Annual cancer risk to MEI: $4 \times 10^{-7} - 5 \times 10^{-5}$ per year
Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined
Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined
	Human Health: Chemical	
Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater
	Water	
Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination
	Ecology	
Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination

B. Ungrouted

Impacts from Disposal as Ungrouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted U_3O_8 in Vaults	Impacts from Disposal as Ungrouted U_3O_8 in a Mine
	Human Health: Radiological	
General Public: Annual dose to MEI: 41 – 60 mrem/yr	**General Public:** Annual dose to MEI: 48 – 70 mrem/yr	**General Public:** Annual dose to MEI: 1 – 93 mrem/yr
Annual cancer risk to MEI: $2 \times 10^{-5} - 3 \times 10^{-5}$ per year	Annual cancer risk to MEI: $2 \times 10^{-5} - 4 \times 10^{-5}$ per year	Annual cancer risk to MEI: $4 \times 10^{-7} - 5 \times 10^{-5}$ per year
Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined
Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined

TABLE I.4 (Cont.)

Impacts from Disposal as Ungrouted U_3O_8 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted U_3O_8 in Vaults	Impacts from Disposal as Ungrouted U_3O_8 in a Mine
	Human Health: Chemical	
Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater
	Water	
Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination
	Ecology	
Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination

[a] Impacts for the post-closure phase were calculated for a time 1,000 years after each disposal facility was assumed to fail. Impacts are presented for a generic wet setting; no impacts would be expected within 1,000 years in a dry setting.

[b] All disposal facilities would be designed to contain the waste material for at least hundreds of years. Shallow earthen structures would be expected to last several hundred years before failure; vaults and mines would be expected to last several hundreds to thousands of years before failure.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual.

TABLE I.5 Summary of Disposal Option Impacts for UO_2 during the Post-Closure Phase[a,b]

A. Grouted

Impacts from Disposal as Grouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Grouted UO_2 in Vaults	Impacts from Disposal as Grouted UO_2 in a Mine
	Human Health: Radiological	
General Public: Annual dose to MEI: 37 – 54 mrem/yr	**General Public:** Annual dose to MEI: 38 – 56 mrem/yr	**General Public:** Annual dose to MEI: 1 – 84 mrem/yr
Annual cancer risk to MEI: $2 \times 10^{-5} - 3 \times 10^{-5}$ per year	Annual cancer risk to MEI: $2 \times 10^{-5} - 3 \times 10^{-5}$ per year	Annual cancer risk to MEI: $3 \times 10^{-7} - 4 \times 10^{-5}$ per year
Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined
Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined
	Human Health: Chemical	
Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater
	Water	
Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination
	Ecology	
Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination

B. Ungrouted

Impacts from Disposal as Ungrouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted UO_2 in Vaults	Impacts from Disposal as Ungrouted UO_2 in a Mine
	Human Health: Radiological	
General Public: Annual dose to MEI: 34 – 50 mrem/yr	**General Public:** Annual dose to MEI: 34 – 50 mrem/yr	**General Public:** Annual dose to MEI: 1 – 77 mrem/yr
Annual cancer risk to MEI: $2 \times 10^{-5} - 3 \times 10^{-5}$ per year	Annual cancer risk to MEI: $2 \times 10^{-5} - 3 \times 10^{-5}$ per year	Annual cancer risk to MEI: $2 \times 10^{-7} - 4 \times 10^{-5}$ per year
Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined	Collective dose to population within 50 miles: not determined
Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined	Number of LCFs in population within 50 miles: not determined

TABLE I.5 (Cont.)

Impacts from Disposal as Ungrouted UO_2 in Shallow Earthen Structures	Impacts from Disposal as Ungrouted UO_2 in Vaults	Impacts from Disposal as Ungrouted UO_2 in a Mine
	Human Health: Chemical	
Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater	Potential impacts to MEI of the general public from groundwater
	Water	
Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination	Potential large impact to groundwater quality from uranium contamination
	Ecology	
Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination	Potential moderate impacts to wetlands and aquatic biota from surface water and groundwater contamination

[a] Impacts for the post-closure phase were calculated for a time 1,000 years after each disposal facility was assumed to fail. Impacts are presented for a generic wet setting; no impacts would be expected within 1,000 years in a dry setting.

[b] All disposal facilities would be designed to contain the waste material for at least hundreds of years. Shallow earthen structures would be expected to last several hundred years before failure; vaults and mines would be expected to last several hundreds to thousands of years before failure.

Notation: LCF = latent cancer fatality; MEI = maximally exposed individual.

- ***U_3O_8 or UO_2.*** Overall, the potential environmental impacts tend to be slightly larger for U_3O_8 than for UO_2 because the volume of U_3O_8 requiring disposal would be greater than that for UO_2. A larger volume essentially exposes a greater area of waste to infiltrating water.

- ***Grouted or Ungrouted Waste.*** For both U_3O_8 and UO_2, the disposal of grouted waste would have larger environmental impacts than disposal of ungrouted waste once the waste was exposed to the environment because grouting would increase the waste volume. However, further studies using site-specific soil characteristics are necessary to determine the effect of grouting on long-term waste mobility. Grouting might reduce the dissolution rate of the waste and subsequent leaching of uranium into the groundwater in the first several hundred years after failure. However, over longer periods the grouted form would be expected to deteriorate and, because of the long half-life of uranium, the performance of grouted and ungrouted waste would be essentially the same. Depending on soil properties and characteristics of the grout material, it is also possible that grouting could increase the solubility of the uranium material by providing a carbonate-rich environment.

- ***Shallow Earthen Structure, Vault, or Mine.*** Because of the long time periods considered and the fact that the calculations were performed for a time of 1,000 years *after* each facility was assumed to fail, the potential impacts are very similar for disposal in a shallow earthen structure, vault, or mine. However, shallow earthen structures would be expected to contain the waste material for a period of at least several hundred years before failure, whereas vaults and a mine would be expected to last even longer — from several hundred years to a thousand years or more. Therefore, vault and mine disposal would provide greater protection of waste in a wet environment. In addition, a vault and a mine would be expected to provide additional protection against erosion of the cover material (and possible surface exposure of the waste material) compared to shallow earthen structures. The exact time that any disposal facility would perform as designed would depend on the specific facility design and site characteristics.

I.2 DESCRIPTION OF OPTIONS

This section provides a brief summary of the different disposal options considered in the assessment of disposal impacts. The information is based on preconceptual design data provided in the engineering analysis report (LLNL 1997). The engineering analysis report includes much more detailed information, such as descriptions of facility layouts, resource requirements, estimates of effluents, wastes, and emissions, and descriptions of potential accident scenarios.

The three disposal options considered are (1) shallow earthen structures (engineered "trenches"), (2) vaults, and (3) an underground mine. For each option, the U_3O_8 and UO_2 would be packaged for disposal as follows:

- U_3O_8 would be disposed of in 55-gal (208-L) drums. If ungrouted, approximately 714,000 drums would be required; if grouted, approximately 1,500,000 drums would be required.

- UO_2 would be disposed of in 30-gal (110-L) drums. These small drums would be used because of the greater density of UO_2 — a filled 30-gal (110-L) drum would weigh about 2,350 lb (1,070 kg). If ungrouted, approximately 420,000 drums would be required; if grouted, approximately 630,000 drums would be required.

All disposal options would include a central wasteform facility where drums of uranium oxide would be received from the conversion facility and prepared for disposal. The wasteform facility would include an administration building, a receiving warehouse, and cementing/curing/short-term storage buildings (if necessary). Grouting of waste would be performed by mechanically mixing the uranium oxide with cement in large tanks and then pouring the mixture into drums. Once prepared for disposal (if necessary), drums would be moved into disposal units. For the grouted U_3O_8 option, the area of the wasteform facility would be approximately 9 acres (3.6 ha); for the grouted UO_2 option, the area would be about 6 acres (2.4 ha). For ungrouted disposal options, only about 4 acres (1.6 ha) would be required because the facilities for grouting, curing, and additional short-term storage would not be needed. The unique features of each disposal option are described in Sections I.2.1 through I.2.3.

I.2.1 Disposal in Shallow Earthen Structures

Shallow earthen structures, commonly referred to as engineered trenches, are among the most commonly used forms of low-level waste disposal, especially in dry climates. Shallow earthen structures would be excavated to a depth of about 26 ft (8 m), with the length and width determined by site conditions and the annual volume of waste to be disposed of. Disposal in shallow earthen structures would consist of placing waste on a stable structural pad with barrier walls constructed of compacted clay. Clay would be used because it prevents the walls from collapsing or caving in, and it presents a relatively impermeable barrier to waste migration. The waste containers (i.e., drums) would be tightly stacked three pallets high in the bottom of the structure with forklifts. Any open space between containers would be filled with earth, sand, gravel, or other similar material as each layer of drums was placed. After the structure was filled, a 6 ft (2 m) thick cap composed of engineered fill dirt and clay would be placed on top and compacted. The cap would be mounded at least 3 ft (1 m) above the local grade and sloped to minimize the potential for water infiltration. Disposal of ungrouted and grouted U_3O_8 would require about 42 acres (17 ha) and 76 acres (31 ha), respectively. Disposal of ungrouted and grouted UO_2 would require about 24 acres (10 ha) and 33 acres (14 ha), respectively.

I.2.2 Disposal in Vaults

Vaults for disposal would be similar to those described previously for the storage options (Appendix G, Section G.2.3), except that each vault would be divided into five sections, each section approximately 66 ft (20 m) long by 26 ft (8 m) wide and 13 ft (4 m) tall. As opposed to shallow earthen structures, the walls and floor of a vault would be constructed of reinforced concrete. A crane would be used to place drums within each section. Once a vault was full, any open space between containers would be filled with earth, sand, gravel, or other similar material. A permanent roof slab of reinforced concrete that completely covers the vault would be installed after all five sections were filled. A cap of engineered fill dirt and clay would be placed on top of the concrete cover and compacted. The cap would be mounded above the local grade and sloped to minimize the potential for water infiltration. Disposal of ungrouted and grouted U_3O_8 would require about 71 and 140 acres (28 and 56 ha), respectively. Disposal of ungrouted and grouted UO_2 would require about 24 and 35 acres (10 and 15 ha), respectively.

I.2.3 Disposal in a Mine

An underground mine disposal facility would be a repository for permanent deep geological disposal. A mined disposal facility could possibly use a previously existing mine, or be constructed for the sole purpose of waste disposal. For purposes of comparing alternatives, the conservative assumption of constructing a new mine was assessed for this PEIS. A mine disposal facility would consist of surface facilities that provide space for waste receiving and inspection (the wasteform facility), and shafts and ramps for access to and ventilation of the underground portion of the repository. The underground portion would consist of tunnels (called "drifts") for the transport and disposal of waste underground. The dimensions of the drifts would be similar to those described previously for the storage options (Section G.2.4), except that each drift would have a width of 21 ft (6.5 m). Waste containers would be placed in drifts and backfilled. Disposal of ungrouted and grouted U_3O_8 would require about 228 acres (91 ha) and 462 acres (185 ha) of underground disposal space, respectively. Disposal of ungrouted and grouted UO_2 would require about 98 acres (39 ha) and 143 acres (57 ha), respectively.

I.2.4 Disposal Technologies and Chemical Forms Considered But Not Analyzed

Disposal of depleted uranium metal was not considered because uranium metal is not as chemically stable as U_3O_8 or UO_2. Uranium metal is subject to surface oxidation. Similarly, disposal of UF_6 and UF_4 were not considered because they react with water to form HF, which is a hazardous and corrosive chemical that would degrade the containment for the waste material. These characteristics are considered unacceptable for disposal.

I.3 IMPACTS OF OPTIONS — OPERATIONAL PHASE

Potential impacts analyzed for the operational phase of the disposal options included impacts occurring during facility construction and during the 20-year period when the waste material would be actively placed into disposal units. (The potential environmental impacts for the post-closure period, after the disposal facility ceased operations, are presented in Section I.4). The estimated impacts are discussed for each area of impact. Information related to the assessment methodologies is provided in Appendix C.

The environmental impacts from the operational phase were evaluated based on the information described in the engineering analysis report (LLNL 1997). The following general assumptions apply to the assessment of impacts:

- Impacts during the operational phase include those from preliminary facility construction and the 20-year period (2008 to 2028) when waste material (i.e., depleted uranium oxide from the DOE-generated inventory) would be actively placed into disposal units. Construction of disposal units would continue over the 20-year period while waste material was being received.

- Ungrouted U_3O_8 and ungrouted UO_2 would be disposed of directly without additional processing at the disposal facility. Consequently, no air or water emissions would be associated with normal (nonaccident) operations, except for exhaust emissions from equipment used during disposal.

- Grouting of U_3O_8 and UO_2 would occur at the disposal facility and consist of mixing the uranium material with cement and pouring it into drums. Grouting operations would result in the release of small amounts of uranium material to the air and water during normal operations.

- The potential impacts from disposal were analyzed for generic dry and wet environmental settings. The historical meteorological conditions for five actual "dry" locations in the southwestern United States and five actual "wet" locations in the central and southeastern United States were used to develop estimates for the generic sites. It was assumed that a disposal facility would not be located in an urban area. Therefore, analyses for both dry and wet environmental settings assumed a rural population density corresponding to 15 persons/mi^2 (6 persons/km^2).

The potential environmental impacts from the disposal options were not evaluated on a site-specific basis because the location of a disposal facility would not be chosen until sometime in the future (see Chapter 3). A more detailed assessment of site considerations would be addressed, as appropriate, as part of the Phase II reviews of the programmatic *National Environmental Policy Act* (NEPA) approach.

I.3.1 Human Health — Normal Operations

I.3.1.1 Radiological Impacts

Radiological impacts during normal operations of the facility were estimated for involved workers, noninvolved workers, and members of the general public. External radiation resulting from the handling and shipping of uranium materials would be the major source of exposure for involved workers. Because grouted waste would increase the total volume of waste substantially, thereby increasing the number of waste containers for handling and shipping, impacts to involved workers would be greater from grouted waste than ungrouted waste. Variations in exposures for the three disposal types considered (shallow earthen structures, vaults, or mine) would be caused by different practices for different technologies. Disposal in a mine would require transport of waste containers from the ground surface to the underground cavities, whereas disposal in shallow earthen structures and vaults would require filling and capping efforts to cover the waste containers with dirt, cement, and/or other engineering materials. In general, average radiation exposure of involved workers would be less than 630 mrem/yr.

Exposures for noninvolved workers and the general public would result from releases of uranium compounds from the grouting facility. Radiation doses from both airborne and waterborne pathways would be less than 0.05 mrem/yr and would tend to be similar between dry and wet environmental settings.

The estimated results for different disposal options are listed in Tables I.6 and I.7. Detailed discussions of the methodology used in the radiological impact analyses are provided in Appendix C and Cheng et al. (1997).

I.3.1.1.1 Disposal as U_3O_8

The total collective doses to involved workers from grouted waste would be nearly twice those from ungrouted waste, ranging from approximately 24 person-rem/yr for 85 workers for shallow earthen structures to 36 person-rem/yr for 87 workers for a mine. The corresponding collective cancer risks for grouted waste would be about 1×10^{-2} fatalities per year (1 additional latent cancer fatality [LCF] in 100 years). The estimated average individual doses to involved workers range from 210 mrem/yr (disposal in vaults) to 410 mrem/yr (disposal in a mine) for grouted

TABLE I.6 Radiological Doses from Disposal Options for Normal Operations

	Dose to Receptor					
	Involved Worker[b]		Noninvolved Worker[c]		General Public[d]	
Option/Location[a]	Average Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)
Disposal as Grouted U_3O_8						
Shallow earthen structure						
Dry	290	24	3.2×10^{-3} – 5.1×10^{-3}	8.1×10^{-5} – 1.2×10^{-4}	9.0×10^{-3} – 1.6×10^{-2}	2.1×10^{-3} – 3.9×10^{-3}
Wet	290	24	2.1×10^{-3} – 8.8×10^{-3}	2.7×10^{-5} – 1.7×10^{-4}	6.1×10^{-3} – 2.6×10^{-2}	1.9×10^{-3} – 5.4×10^{-3}
Vault						
Dry	210	26	3.2×10^{-3} – 5.1×10^{-3}	8.9×10^{-5} – 1.3×10^{-4}	4.7×10^{-3} – 1.4×10^{-2}	2.1×10^{-3} – 3.9×10^{-3}
Wet	210	26	2.1×10^{-3} – 8.8×10^{-3}	3.0×10^{-5} – 1.9×10^{-4}	6.0×10^{-3} – 2.0×10^{-2}	1.9×10^{-3} – 5.4×10^{-3}
Mine						
Dry	410	36	3.0×10^{-3} – 4.7×10^{-3}	8.5×10^{-5} – 1.3×10^{-4}	6.7×10^{-3} – 1.6×10^{-2}	2.1×10^{-3} – 3.9×10^{-3}
Wet	410	36	8.4×10^{-4} – 8.5×10^{-3}	2.8×10^{-5} – 1.8×10^{-4}	6.1×10^{-3} – 2.6×10^{-2}	1.9×10^{-3} – 5.4×10^{-3}
Disposal as Ungrouted U_3O_8						
Shallow earthen structure						
Dry	550	14	0	0	0	0
Wet	550	14	0	0	0	0
Vault						
Dry	330	15	0	0	0	0
Wet	330	15	0	0	0	0
Mine						
Dry	630	18	0	0	0	0
Wet	630	18	0	0	0	0

TABLE I.6 (Cont.)

	Dose to Receptor					
	Involved Worker[b]		Noninvolved Worker[c]		General Public[d]	
Option/Location[a]	Average Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose (mrem/yr)	Collective Dose (person-rem/yr)
Disposal as Grouted UO_2						
Shallow earthen structure						
Dry	300	21	6.0×10^{-3} – 9.8×10^{-3}	8.3×10^{-5} – 1.2×10^{-4}	1.7×10^{-2} – 3.0×10^{-2}	3.9×10^{-3} – 7.5×10^{-3}
Wet	300	21	3.2×10^{-3} – 1.7×10^{-2}	2.8×10^{-5} – 1.8×10^{-4}	1.2×10^{-2} – 5.0×10^{-2}	3.6×10^{-3} – 1.0×10^{-2}
Vault						
Dry	300	22	6.0×10^{-3} – 9.8×10^{-3}	9.1×10^{-5} – 1.4×10^{-4}	1.3×10^{-2} – 3.0×10^{-2}	3.9×10^{-3} – 7.5×10^{-3}
Wet	300	22	3.7×10^{-3} – 1.7×10^{-2}	3.0×10^{-5} – 2.0×10^{-4}	1.2×10^{-2} – 5.0×10^{-2}	3.6×10^{-3} – 1.0×10^{-2}
Mine						
Dry	330	24	5.7×10^{-3} – 8.9×10^{-3}	8.3×10^{-5} – 1.2×10^{-4}	1.3×10^{-2} – 3.0×10^{-2}	3.9×10^{-3} – 7.5×10^{-3}
Wet	330	24	1.6×10^{-3} – 1.6×10^{-2}	2.8×10^{-5} – 1.8×10^{-4}	1.2×10^{-2} – 5.0×10^{-2}	3.6×10^{-3} – 1.0×10^{-2}
Disposal as Ungrouted UO_2						
Shallow earthen structure						
Dry	360	8.3	0	0	0	0
Wet	360	8.3	0	0	0	0
Vault						
Dry	430	11	0	0	0	0
Wet	430	11	0	0	0	0
Mine						
Dry	470	12	0	0	0	0
Wet	470	12	0	0	0	0

[a] Two generic environmental settings were considered for each option, corresponding to a dry environment and wet environment, respectively.

[b] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual dose and collective dose for the worker population. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[c] Noninvolved workers are individuals who do not participate in material-handing activities, such as employees in the administration building. The number of noninvolved workers would be approximately 44.

[d] The off-site general public is defined as residents who live within a radius of 50 miles (80 km) around the disposal site. A rural environment with a population density of 6 persons/km^2 and a total population of 120,000 was assumed. Impacts to the MEI were assessed from both airborne and waterborne emissions; impacts to the total population were assessed from airborne emissions only.

TABLE I.7 Latent Cancer Risks from Disposal Options for Normal Operations

	Risk to Receptor					
	Involved Worker[b]		Noninvolved Worker[c]		General Public[d]	
Option/Location[a]	Average Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk (risk/yr)	Collective Risk (fatalities/yr)
Disposal as Grouted U_3O_8						
Shallow earthen structure						
Dry	1×10^{-4}	1×10^{-2}	1×10^{-9}– 2×10^{-9}	3×10^{-8}– 5×10^{-8}	4×10^{-9}– 8×10^{-9}	1×10^{-6}– 2×10^{-6}
Wet	1×10^{-4}	1×10^{-2}	8×10^{-10}– 4×10^{-9}	1×10^{-8}– 7×10^{-8}	3×10^{-9}– 1×10^{-8}	9×10^{-7}– 3×10^{-6}
Vault						
Dry	8×10^{-5}	1×10^{-2}	1×10^{-9}– 2×10^{-9}	4×10^{-8}– 5×10^{-8}	2×10^{-9}– 7×10^{-9}	1×10^{-6}– 2×10^{-6}
Wet	8×10^{-5}	1×10^{-2}	8×10^{-10}– 4×10^{-9}	1×10^{-8}– 8×10^{-8}	3×10^{-9}– 1×10^{-8}	9×10^{-7}– 3×10^{-6}
Mine						
Dry	2×10^{-4}	1×10^{-2}	1×10^{-9}– 2×10^{-9}	3×10^{-8}– 5×10^{-8}	3×10^{-9}– 8×10^{-9}	1×10^{-6}– 2×10^{-6}
Wet	2×10^{-4}	1×10^{-2}	3×10^{-10}– 3×10^{-9}	1×10^{-8}– 7×10^{-8}	3×10^{-9}– 1×10^{-8}	9×10^{-7}– 3×10^{-6}
Disposal as Ungrouted U_3O_8						
Shallow earthen structure						
Dry	2×10^{-4}	6×10^{-3}	0	0	0	0
Wet	2×10^{-4}	6×10^{-3}	0	0	0	0
Vault						
Dry	1×10^{-4}	6×10^{-3}	0	0	0	0
Wet	1×10^{-4}	6×10^{-3}	0	0	0	0
Mine						
Dry	3×10^{-4}	7×10^{-3}	0	0	0	0
Wet	3×10^{-4}	7×10^{-3}	0	0	0	0

TABLE I.7 (Cont.)

	Risk to Receptor					
	Involved Worker[b]		Noninvolved Worker[c]		General Public[d]	
Option/Location[a]	Average Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk (risk/yr)	Collective Risk (fatalities/yr)
Disposal as Grouted UO_2						
Shallow earthen structure						
Dry	1×10^{-4}	8×10^{-3}	2×10^{-9}– 4×10^{-9}	3×10^{-8}– 5×10^{-8}	9×10^{-9}– 2×10^{-8}	2×10^{-6}– 4×10^{-6}
Wet	1×10^{-4}	8×10^{-3}	1×10^{-9}– 7×10^{-9}	1×10^{-8}– 7×10^{-8}	6×10^{-9}– 2×10^{-8}	2×10^{-6}– 5×10^{-6}
Vault						
Dry	1×10^{-4}	9×10^{-3}	2×10^{-9}– 4×10^{-9}	4×10^{-8}– 5×10^{-8}	6×10^{-9}– 2×10^{-8}	2×10^{-6}– 4×10^{-6}
Wet	1×10^{-4}	9×10^{-3}	1×10^{-9}– 7×10^{-9}	1×10^{-8}– 8×10^{-8}	6×10^{-9}– 2×10^{-8}	2×10^{-6}– 5×10^{-6}
Mine						
Dry	1×10^{-4}	1×10^{-2}	2×10^{-9}– 4×10^{-9}	3×10^{-8}– 5×10^{-8}	6×10^{-9}– 2×10^{-8}	2×10^{-6}– 4×10^{-6}
Wet	1×10^{-4}	1×10^{-2}	6×10^{-10}– 6×10^{-9}	1×10^{-8}– 7×10^{-8}	6×10^{-9}– 2×10^{-8}	2×10^{-6}– 5×10^{-6}
Disposal as Ungrouted UO_2						
Shallow earthen structure						
Dry	1×10^{-4}	3×10^{-3}	0	0	0	0
Wet	1×10^{-4}	3×10^{-3}	0	0	0	0
Vault						
Dry	2×10^{-4}	4×10^{-3}	0	0	0	0
Wet	2×10^{-4}	4×10^{-3}	0	0	0	0
Mine						
Dry	2×10^{-4}	5×10^{-3}	0	0	0	0
Wet	2×10^{-4}	5×10^{-3}	0	0	0	0

[a] Two generic environmental settings were considered for each option, corresponding to a dry environment and wet environment, respectively.

[b] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual risk and collective risk for the worker population.

[c] Noninvolved workers are individuals who do not participate in material-handling activities, such as employees in the administration building. The number of noninvolved workers would be approximately 44.

[d] The off-site general public is defined as residents who live within a radius of 50 miles (80 km) around the disposal site. A rural environment with a population density of 6 persons/km^2 and a total population of 120,000 was assumed. Impacts to the MEI were assessed from both airborne and waterborne emissions; impacts to the total population were assessed from airborne emissions only.

waste. Average worker doses for ungrouted waste range from 330 to 630 mrem/yr. Potential exposures of involved workers would be well below the radiation dose limit of 5,000 mrem/yr (10 CFR Part 835).

Radiation exposures of noninvolved workers would occur only for disposal of grouted waste. The radiation dose to the maximally exposed individual (MEI) would be less than 0.0088 mrem/yr, a small fraction of the dose limit of 10 mrem/yr from airborne emissions (10 CFR Part 61). The collective dose for noninvolved workers would be less than 0.0002 person-rem/yr for a total of approximately 43 workers.

The estimated maximum individual dose to the off-site general public is less than 0.026 mrem/yr for grouted waste, which corresponds to a cancer risk of 1 in 80 million per year. For a collective population of 120,000 persons within 50 miles (80 km) of the site, the estimated number of LCFs is less than 3×10^{-6} per year (1 fatality in 300,000 years).

I.3.1.1.2 Disposal as UO_2

Compared with the disposal of U_3O_8, disposal of UO_2 would result in less collective exposures of involved workers because of the smaller volume of waste involved. Grouted UO_2 would result in larger collective worker doses than ungrouted UO_2, with the collective dose ranging from 21 to 24 person-rem/yr for approximately 72 workers. The average individual dose to involved workers for grouted waste ranges from 300 to 330 mrem/yr. Although ungrouted waste would result in less collective exposure, the number of involved workers (about 25) would also be less. As a result, the average worker dose would be greater for ungrouted waste than grouted waste. The estimated average individual worker dose ranges from 360 mrem/yr to 470 mrem/yr. For all disposal types considered, the average radiation doses to involved workers would be well below the dose limit of 5,000 mrem/yr. The estimated maximum individual dose to noninvolved workers is less than 0.017 mrem/yr, and the estimated collective dose is less than 0.0002 person-rem/yr. The number of noninvolved workers would be approximately 44.

The maximum individual dose to the off-site general public would be less than 0.050 mrem/yr, which corresponds to a cancer risk of 1 in 40 million per year. For the assumed rural collective population of 120,000 persons within 50 miles (80 km) of the site, the number of LCFs would be less than 5×10^{-6} per year (1 fatality in 200,000 years of operation).

I.3.1.2 Chemical Impacts

Potential chemical impacts to human health from normal operations at the disposal facilities would result primarily from exposure to the insoluble uranium compounds, UO_2 and U_3O_8. Risks from normal operations were quantified on the basis of calculated hazard indices. Additional information on the exposure assumptions, health effects assumptions, reference doses used for uranium compounds, and calculational methods used in the chemical impact analysis are provided in Appendix C and Cheng et al. (1997).

Chemical impacts during the operational phase of the disposal facilities were calculated for noninvolved workers and the general public. Exposures of noninvolved workers and the general public to low levels of airborne emissions could occur from mixing uranium with cement and other grouting materials in the wasteform facility. Three disposal types (shallow earthen structures, vaults, and mines) were considered for U_3O_8 and UO_2 as both grouted and ungrouted wastes in generic dry and wet environmental settings.

Human health impacts from exposures to hazardous chemicals during normal operations of the U_3O_8 or UO_2 disposal facilities are summarized in Table I.8. Two waste forms were evaluated for U_3O_8 and UO_2: grouted and ungrouted. For grouted wastes, the range of chemical exposures to the noninvolved workers and general public would result primarily from differences between the locations and types of disposal facilities. The hazard indices for all disposal options are four orders of magnitude less than 1, the level for which potential adverse health effects could occur from normal operations. No impacts would occur for disposal of ungrouted U_3O_8 or UO_2 because airborne emissions would not be expected (LLNL 1997).

I.3.2 Human Health — Accident Conditions

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents has been presented in the engineering analysis report (LLNL 1997). These accidents are listed in Table I.9. The following sections present the results for radiological and chemical health impacts of the highest consequence accident in each frequency category. Results for all accidents listed in Table I.9 are presented in Policastro et al. (1997). Detailed descriptions of the methodology and assumptions used in these calculations are also provided in Appendix C and Policastro et al. (1997).

I.3.2.1 Radiological Impacts

The radiological doses to various receptors for the accidents that give the highest dose from each frequency category are listed in Table I.10. The LCF risks for these accidents are given in Table I.11. The doses and the risks are presented as ranges (maximum and minimum) because two different meteorological conditions (wet and dry) were evaluated for each disposal option (see Appendix C). The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely category have a probability of

TABLE I.8 Chemical Impacts to Human Health for the Disposal Options under Normal Operations

	Impacts to Receptor[a]			
	Noninvolved Workers[b]		General Public	
Option	Hazard Index for MEI[c]	Population Risk[d] (ind. at risk/yr)	Hazard Index for MEI[c]	Population Risk[d] (ind. at risk/yr)
Disposal as Grouted U_3O_8				
Shallow earthen structure				
Dry	3.9×10^{-7}–6.3×10^{-7}	–	3.1×10^{-5}–5.3×10^{-5}	–
Wet	2.5×10^{-7}–1.1×10^{-6}	–	2.1×10^{-5}–8.9×10^{-5}	–
Vault				
Dry	3.9×10^{-7}–6.3×10^{-7}	–	1.6×10^{-5}–3.8×10^{-5}	–
Wet	3.1×10^{-7}–1.1×10^{-6}	–	2.0×10^{-5}–6.6×10^{-5}	–
Mine				
Dry	3.6×10^{-7}–5.4×10^{-7}	–	3.3×10^{-5}–5.3×10^{-5}	–
Wet	1.0×10^{-7}–1.1×10^{-6}	–	2.1×10^{-5}–9.1×10^{-5}	–
Disposal as Ungrouted U_3O_8				
Shallow earthen structure				
Dry	~0	–	~0	–
Wet	~0	–	~0	–
Vault				
Dry	~0	–	~0	–
Wet	~0	–	~0	–
Mine				
Dry	~0	–	~0	–
Wet	~0	–	~0	–

TABLE I.8 (Cont.)

	Impacts to Receptor[a]			
	Noninvolved Workers[b]		General Public	
Option	Hazard Index for MEI[c]	Population Risk[d] (ind. at risk/yr)	Hazard Index for MEI[c]	Population Risk[d] (ind. at risk/yr)
Disposal as Grouted UO_2				
Shallow earthen structure				
Dry	7.2×10^{-7}–1.2×10^{-6}	–	5.7×10^{-5}–9.7×10^{-5}	–
Wet	3.8×10^{-7}–2.0×10^{-6}	–	3.9×10^{-5}–1.6×10^{-4}	–
Vault				
Dry	7.2×10^{-7}–1.2×10^{-6}	–	6.0×10^{-5}–9.7×10^{-5}	–
Wet	4.6×10^{-7}–2.0×10^{-6}	–	3.9×10^{-5}–1.7×10^{-4}	–
Mine				
Dry	6.5×10^{-7}–9.9×10^{-7}	–	6.0×10^{-5}–9.7×10^{-5}	–
Wet	1.9×10^{-7}–1.8×10^{-6}	–	3.9×10^{-5}–1.7×10^{-4}	–
Disposal as Ungrouted UO_2				
Shallow earthen structure				
Dry	~0	–	~0	–
Wet	~0	–	~0	–
Vault				
Dry	~0	–	~0	–
Wet	~0	–	~0	–
Mine				
Dry	~0	–	~0	–
Wet	~0	–	~0	–

[a] The range of impacts represent variations in meteorological conditions at the generic wet and dry environmental settings.

[b] Noninvolved workers are individuals who do not participate in material-handling activities, such as employees in the administration building.

[c] The hazard index is an indicator for potential health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

[d] Calculation of population risk is not applicable when the corresponding hazard index for the MEI is less than 1.

TABLE I.9 Accidents Considered for the Disposal Options

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Disposal as Grouted U_3O_8					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/ billet inside the product receiving area	A single U_3O_8 drum is damaged by a forklift and spills its contents onto the ground inside the product receiving area.	U_3O_8	0.00028	Puff	Stack
Mishandling/drop of drum/ billet outside	A single U_3O_8 drum is damaged by a forklift and spills its contents outside without HEPA filtration.	U_3O_8	0.000066	Puff	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The product receiving area and cement mixing area are damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	U_3O_8	400	Puff	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the product receiving area and cement mixing area structures and confinement systems.	U_3O_8	770	Puff	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire/explosion inside the product mixing area	A fire or explosion within the product mixing area affects the contents of a single pallet of drums.	U_3O_8	0.0017	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Disposal as Ungrouted U_3O_8					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/ billet inside the product receiving area	A single U_3O_8 drum is damaged by a forklift and spills its contents onto the ground inside the product receiving area.	U_3O_8	0.00028	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The product receiving area is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	U_3O_8	370	Puff	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the product receiving structure and confinement systems.	U_3O_8	740	Puff	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA

TABLE I.9 (Cont.)

Option/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Disposal as Grouted UO_2					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/ billet inside the product receiving area	A single UO_2 drum is damaged by a forklift and spills its contents onto the ground inside the product receiving area.	UO_2	0.00011	Puff	Stack
Mishandling/drop of drum/ billet outside	A single UO_2 drum is damaged by a forklift and spills its contents outside without HEPA filtration.	UO_2	0.00015	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The product receiving area and cement mixing area are damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	UO_2	0.73	Puff	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the product receiving area and cement mixing area structures and confinement systems.	UO_2	2.1	Puff	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Fire/explosion inside the product mixing area	A fire or explosion within the product mixing area affects the contents of a single pallet of drums.	UO_2	0.00068	Puff	Stack
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA
Disposal as Ungrouted UO_2					
Likely Accidents (frequency: 1 or more times in 100 years)					
Mishandling/drop of drum/ billet inside product receiving area	A single UO_2 drum is damaged by a forklift and spills its contents onto the ground inside the product receiving area.	UO_2	0.00011	Puff	Stack
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Earthquake	The product receiving area is damaged during a design-basis earthquake, resulting in failure of the structure and confinement systems.	UO_2	0.59	Puff	Ground
Tornado	A major tornado and associated tornado missiles result in failure of the product receiving structure and confinement systems.	UO_2	1.2	Puff	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Flood	The facility would be located at a site that would preclude severe flooding.	No release	NA	NA	NA

[a] Ground-level releases were assumed to occur outdoors on concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

Notation: HEPA = high-efficiency particulate air; NA = not applicable; UO_2 = uranium dioxide; U_3O_8 = triuranium octaoxide.

TABLE I.10 Estimated Radiological Doses per Accident Occurrence for the Disposal Options

		Maximum Dose[c]				Minimum Dose[c]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[a]	Frequency Category[b]	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Disposal as Grouted U_3O_8									
Mishandling/drop of drum/billet outside	L	4.1×10^{-7}	3.7×10^{-8}	1.3×10^{-8}	7.6×10^{-8}	4.1×10^{-7}	3.7×10^{-8}	1.0×10^{-8}	7.6×10^{-8}
Earthquake	U	1.4×10^{2}	6.1	1.1	1.5	1.3×10^{1}	1.1	2.9×10^{-1}	8.7×10^{-1}
Fire or explosion inside the product mixing area	EU	5.5×10^{-8}	1.1×10^{-7}	5.7×10^{-8}	2.2×10^{-6}	1.6×10^{-11}	3.1×10^{-11}	2.8×10^{-9}	1.0×10^{-6}
Disposal as Ungrouted U_3O_8									
Mishandling/drop of drum inside the product receiving area	L	9.0×10^{-9}	1.8×10^{-8}	9.3×10^{-9}	3.6×10^{-7}	2.7×10^{-12}	5.1×10^{-12}	4.6×10^{-10}	1.6×10^{-7}
Earthquake	U	1.3×10^{2}	5.6	1.0	1.3	1.2×10^{1}	9.8×10^{-1}	2.7×10^{-1}	8.0×10^{-1}
Disposal as Grouted UO_2									
Mishandling/drop of drum/billet outside	L	9.8×10^{-7}	8.7×10^{-8}	3.0×10^{-8}	1.8×10^{-7}	9.8×10^{-7}	8.7×10^{-8}	2.4×10^{-8}	1.8×10^{-7}
Earthquake	U	2.7×10^{-1}	1.1×10^{-2}	2.1×10^{-3}	2.7×10^{-3}	2.4×10^{-2}	2.0×10^{-3}	5.5×10^{-4}	1.6×10^{-3}
Fire or explosion inside the product mixing area	EU	2.3×10^{-8}	4.5×10^{-8}	2.4×10^{-8}	9.1×10^{-7}	6.8×10^{-12}	1.3×10^{-11}	1.2×10^{-9}	4.2×10^{-7}
Disposal as Ungrouted UO_2									
Mishandling/drop of drum inside the product receiving area	L	3.7×10^{-9}	7.3×10^{-9}	3.8×10^{-9}	1.5×10^{-7}	1.1×10^{-12}	2.1×10^{-12}	1.9×10^{-10}	6.7×10^{-8}
Earthquake	U	2.2×10^{-1}	9.3×10^{-3}	1.7×10^{-3}	2.2×10^{-3}	1.9×10^{-2}	1.6×10^{-3}	4.4×10^{-4}	1.3×10^{-3}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr).

[c] Maximum and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

TABLE I.11 Estimated Radiological Health Risks per Accident Occurrence for the Disposal Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
		MEI	Population	MEI	Population	MEI	Population	MEI	Population
Disposal as Grouted U_3O_8									
Mishandling/drop of drum/billet outside	L	2×10^{-10}	1×10^{-11}	6×10^{-12}	4×10^{-11}	2×10^{-10}	1×10^{-11}	5×10^{-12}	4×10^{-11}
Earthquake	U	6×10^{-2}	2×10^{-3}	5×10^{-4}	7×10^{-4}	5×10^{-3}	4×10^{-4}	1×10^{-4}	4×10^{-4}
Fire or explosion inside the product mixing area	EU	2×10^{-11}	4×10^{-11}	3×10^{-11}	1×10^{-9}	7×10^{-15}	1×10^{-14}	1×10^{-12}	5×10^{-10}
Disposal as Ungrouted U_3O_8									
Mishandling/drop of drum inside the product receiving area	L	4×10^{-12}	7×10^{-12}	5×10^{-12}	2×10^{-10}	1×10^{-15}	2×10^{-15}	2×10^{-13}	8×10^{-11}
Earthquake	U	5×10^{-2}	2×10^{-3}	5×10^{-4}	7×10^{-4}	5×10^{-3}	4×10^{-4}	1×10^{-4}	4×10^{-4}
Disposal as Grouted UO_2									
Mishandling/drop of drum/billet outside	L	4×10^{-10}	3×10^{-11}	1×10^{-11}	9×10^{-11}	4×10^{-10}	3×10^{-11}	1×10^{-11}	9×10^{-11}
Earthquake	U	1×10^{-4}	5×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-5}	8×10^{-7}	3×10^{-7}	8×10^{-7}
Fire or explosion inside the product mixing area	EU	9×10^{-12}	2×10^{-11}	1×10^{-11}	5×10^{-10}	3×10^{-15}	5×10^{-15}	6×10^{-13}	2×10^{-10}
Disposal as Ungrouted UO_2									
Mishandling/drop of drum inside the product receiving area	L	1×10^{-12}	3×10^{-12}	2×10^{-12}	7×10^{-11}	4×10^{-16}	8×10^{-16}	9×10^{-14}	3×10^{-11}
Earthquake	U	9×10^{-5}	4×10^{-6}	8×10^{-7}	1×10^{-6}	8×10^{-6}	7×10^{-7}	2×10^{-7}	7×10^{-7}

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr).

[d] Maximum and minimum risks reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

- Except for the impacts to a noninvolved worker MEI from an earthquake accident, the maximum radiological dose to noninvolved worker and general public MEIs (assuming an accident occurred) would be 1.1 rem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the U.S. Nuclear Regulatory Commission (NRC 1994).

- For an earthquake accident, the potential dose to the noninvolved worker MEI would range from 0.22 to 140 rem, depending on the option implemented for uranium disposal. The NRC recommendations are not directly applicable to workers but are used in this instance as a guideline to indicate potential for health effects. A dose of 140 rem could result in temporary adverse health effects to the MEI worker.

- The overall radiological risk to worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table I.11] by the annual probability of occurrence by the number of years of operations) would be less than 1 for all of the disposal accidents.

I.3.2.2 Chemical Impacts

The accidents assessed in this section are listed in Table I.9. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables I.12 and I.13. Results are presented as (1) number of people with the potential for adverse effects and (2) number of people with the potential for irreversible adverse effects. The tables present the results for the accident within each frequency category that would affect the largest number of people (total of noninvolved workers and off-site population) (Policastro et al. 1997). The number of workers and members of the off-site public represent the impacts if the associated accident was assumed to occur. These impacts may be summarized as follows:

- If the accidents identified in Tables I.12 and I.13 did occur, the number of persons in the off-site population with potential for adverse effects and irreversible adverse effects would range from 0 to 1 (MEI), the maximum corresponding to an earthquake accident. The number of workers with potential for adverse effects and irreversible adverse effects would range from 0 to 1, the maximum also corresponding to the earthquake accident.

TABLE I.12 Number of Persons with Potential for Adverse Effects from Accidents under the Disposal Options[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Disposal as Grouted U_3O_8									
Mishandle/drop of drum/billet outside[f]	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes	1	Yes[g]	0	Yes	1	No	0
Fire/explosion inside[f]	EU	No	0	No	0	No	0	No	0
Disposal as Grouted UO_2									
Mishandle/drop of drum/billet outside[f]	L	No	0	No	0	No	0	No	0
Earthquake[f]	U	No	0	No	0	No	0	No	0
Fire/explosion inside[f]	EU	No	0	No	0	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (noninvolved workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} - 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum risks reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential adverse effects to an individual.

[f] These accidents would result in the largest plume sizes, although no people would be affected.

[g] MEI locations were evaluated at 100 m from ground-level releases for noninvolved workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because generic worker and general public population distributions were used, which did not show receptors at the MEI locations.

TABLE I.13 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under the Disposal Options[a]

Option/Accident[b]	Frequency Category[c]	Maximum Number of Persons[d]: Noninvolved Workers MEI[e]	Maximum Number of Persons[d]: Noninvolved Workers Population	Maximum Number of Persons[d]: General Public MEI[e]	Maximum Number of Persons[d]: General Public Population	Minimum Number of Persons[d]: Noninvolved Workers MEI[e]	Minimum Number of Persons[d]: Noninvolved Workers Population	Minimum Number of Persons[d]: General Public MEI[e]	Minimum Number of Persons[d]: General Public Population
Disposal as Grouted U_3O_8									
Mishandle/drop of drum/billet outside[f]	L	No	0	No	0	No	0	No	0
Earthquake	U	Yes	1	Yes[g]	0	No	0	No	0
Fire/explosion inside[f]	EU	No	0	No	0	No	0	No	0
Disposal as Grouted UO_2									
Mishandle/drop of drum/billet outside[f]	L	No	0	No	0	No	0	No	0
Earthquake[f]	U	No.	0	No	0	No	0	No	0
Fire/explosion inside[f]	EU	No	0	No	0	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (noninvolved workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum risks reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either "Yes" or "No" for potential irreversible adverse effects to an individual.

[f] These accidents would result in the largest plume sizes, although no people would be affected.

[g] MEI locations were evaluated at 100 m from ground-level releases for noninvolved workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because generic worker and general public population distributions were used, which did not show receptors at the MEI locations.

- There would be no difference in accident consequences for disposal as UO_2 or U_3O_8 in shallow earthen structures, vaults, or a mine.

- The largest impacts would be caused by an earthquake in the product receiving and cement mixing areas. Accidents involving stack emissions would have very small impacts compared with accidents involving releases at ground level due to the large dilution (and lower source terms) involved with the stack emissions.

- For the earthquake accident, the noninvolved worker and the public MEIs could experience potential for both adverse effects and irreversible adverse effects. For all other accidents, the worker and general public MEIs would experience neither potential adverse effects nor potential irreversible adverse effects.

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (20 years, 2009 through 2028). The results indicated that the maximum risk values would be less than 1 for all accidents. These risk values are conservative because the numbers of people affected were based on assuming (1) meteorological conditions that would result in the maximum reasonably foreseeable plume size (i.e., F stability and 1 m/s wind speed) and (2) wind in the direction that would lead to maximum numbers of individuals exposed for workers or for the general population.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible adverse effects was estimated. The bounding case accidents shown in Table I.13 would involve releases of uranium oxide and potential exposure to uranium compounds. If the accident occurred, exposures are estimated to result in death for 1% or fewer of the persons experiencing irreversible adverse effects (Policastro et al. 1997). Thus, for noninvolved workers and members of the general public experiencing a range of 0 to 1 irreversible adverse effects, 0 deaths would be expected.

I.3.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries to all disposal facility workers is calculated using industry-specific statistics from the Bureau of Labor Statistics, as reported by the National Safety Council (1995). Construction and manufacturing annual fatality and injury rates were used, respectively, for the construction and operational components of the disposal facility activities.

One fatality due to accidental physical trauma would be predicted under the grouted U_3O_8 mine disposal option. The risk of a fatality for this option is almost twice as great as the risk for the other options; this difference is due mainly to the increased risk associated with construction of the large mine that would be needed for the entire inventory of grouted U_3O_8. Mitigation of risks from construction, loading, and closure of mines can be accomplished to a certain extent by instituting safety measures and by conducting thorough safety training programs for personnel.

Estimated fatalities range from 0.13 to 0.94, and injury incidences range from 90 to 450 (see Table I.14). Except for the grouted U_3O_8 mine disposal option discussed above, the other options are fairly comparable with respect to predicted fatalities and injuries due to physical trauma.

I.3.3 Air Quality

The methodology used to analyze air quality impacts from disposal options is provided in Appendix C and Tschanz (1997). The pollutant concentrations at several distances from the center of the facility were estimated because of uncertainty regarding the size and location of the generic disposal facility. Estimates at 2,460 ft (750 m) from the center of the disposal facilities are comparable to the estimates for options based on representative environmental settings (i.e., conversion and long-term storage options using the three current storage sites as representative of those settings). The shortest distances from the centers of the representative sites to their boundaries range from 2,300 to 2,600 ft (700 to 800 m).

Pollutant emissions would result from construction of the wasteform facility and construction of the disposal areas/facilities. The annual emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM_{10}), with a mean diameter of 10 µm or less) resulting from construction of the wasteform facility and from construction of disposal areas/facilities are shown in Table I.15 for disposal of grouted U_3O_8 in either shallow earthen structures or vaults. The criteria pollutant emissions from construction of facilities for the other disposal options and for operation of the facilities are related to those in Table I.15 by the scaling factors listed in Table I.16. For example, the CO emissions from operations for disposal of grouted UO_2 in shallow earthen structures would be 0.74×1.55 tons/yr, or 1.14 tons/yr (1.05 metric tons/yr). Operation of the wasteform facility would also produce 1.08 and 0.59 lb/yr (0.50 and 0.27 kg/yr) of uranium emissions for the grouted UO_2 and grouted U_3O_8 options, respectively.

The largest pollutant concentrations would result from the operation of vaults for disposal of grouted U_3O_8. The estimated NO_x concentrations for operation of this option are shown in the bottom half of Table I.17. The concentrations of CO, HC, SO_x, and PM_{10} are 0.21, 0.075, 0.065, and 0.070 times as large, respectively, as those for NO_x. The results show that the ranges of impacts would be larger for a wet environmental setting than for a dry setting, and in fact the ranges of dry setting impacts fall within those for the wet setting. At 2,460 ft (750 m), the maximum annual NO_x concentration during operations might be as large as 37% of the 100 µg/m^3 standard. The other

TABLE I.14 Potential Impacts to Human Health from Physical Hazards under Accident Conditions for the Disposal Options

	Impacts to All Disposal Facility Workers[a]					
	Fatality Incidence[b]			Injury Incidence[b]		
Option	Wasteform Facility	Disposal Facility	Total	Wasteform Facility	Disposal Facility	Total
Disposal as Grouted U_3O_8						
Shallow earthen structure	0.15	0.11	0.26	130	80	210
Vault	0.15	0.29	0.44	130	170	300
Mine	0.15	0.78	0.94	130	320	450
Disposal as Ungrouted U_3O_8						
Shallow earthen structure	0.06	0.08	0.13	50	40	90
Vault	0.06	0.17	0.22	50	90	140
Mine	0.06	0.47	0.53	50	190	240
Disposal as Grouted UO_2						
Shallow earthen structure	0.15	0.08	0.23	120	50	180
Vault	0.15	0.11	0.26	120	70	190
Mine	0.15	0.36	0.50	120	160	280
Disposal as Ungrouted UO_2						
Shallow earthen structure	0.06	0.07	0.13	50	40	90
Vault	0.06	0.10	0.15	50	60	110
Mine	0.06	0.27	0.33	50	120	170

[a] Values are rounded to two significant figures. All construction and operations workers at the disposal facilities were included in the physical hazard risk calculations.

[b] Fatality incidence and injury incidence were calculated as the number of full-time-equivalent employees times the annual fatality rate times the number of years. Only injuries involving lost workdays were included. Injury and fatality incidence rates used in the calculations were taken from National Safety Council (1995).

criteria pollutant concentrations are smaller fractions of their standards than is NO_x relative to its standard.

The NO_x concentrations for construction of the grouted U_3O_8 vault disposal option would be 0.35 times those for operation of the vaults and approximately the same as the estimated NO_x concentrations during operations for the disposal of grouted U_3O_8 in shallow earthen structures, shown in Table I.18. During operations for shallow earthen structure disposal of grouted U_3O_8, the CO, HC, SO_x, and PM_{10} impacts would be 0.22, 0.075, 0.066, and 0.070 times as large, respectively, as those for NO_x. The impacts of all of these other pollutants relative to their standards would be less than that of NO_x.

TABLE I.15 Pollutant Emissions from Construction Activities Associated with Disposal Facilities for Grouted U_3O_8[a]

	Pollutant Emissions from Construction Activities (tons/yr)		
Pollutant	Wasteform Facility	Shallow Earthen Structure	Vault
CO	2.11	1.55	2.62
HC	0.739	0.543	0.918
NO_x	9.79	7.18	12.2
SO_x	0.644	0.473	0.799
PM_{10}	0.688	0.505	0.854

[a] Represents emissions from construction of wasteform facility and from construction of either shallow earthen structures or vaults.

The NO_x concentrations from construction of the wasteform facility for grouted U_3O_8 disposal, shown in the upper half of Table I.17, would be slightly smaller than the NO_x concentrations for construction of vaults for grouted U_3O_8 disposal. However, construction of the wasteform facility would result in smaller ranges of impacts because the construction would take place only on a centrally located area; the ranges in this case reflect only the variability due to the different meteorological data sets used. For construction of the wasteform facility, the CO, HC, SO_x, and PM_{10} impacts relative to the NO_x impacts would be the same as those discussed for operation of the shallow earthen structure disposal of grouted U_3O_8.

Construction and operation would occur simultaneously for most of the operational phase. The combined construction and operations emissions might result in annual NO_x concentrations as large as 45 $\mu g/m^3$ at 2,460 ft (750 m) for the vault disposal of grouted U_3O_8, approaching 50% of the standard.

Operation of the wasteform facility would produce 0.6 lb/yr and 1.1 lb/yr of uranium emissions from the process stack for grouted U_3O_8 and grouted UO_2 suboptions, respectively, but no uranium emissions for the ungrouted suboptions. The impacts of uranium oxides emitted during operation of the wasteform facility for grouted disposal options are shown in Table I.19. Comparing the ranges of concentrations for the wet and dry settings indicates that the uranium emissions from the central point source would produce a slightly wider range of impacts for the dry setting than for the wet setting, in contrast to the wider wet setting impact ranges that would result for criteria pollutants from all the construction and operations area sources.

TABLE I.16 Scaling Factors for Criteria Pollutant Emissions from Construction and Operations for Disposal Options Relative to Emissions from Construction Activities Associated with Disposal Facilities for Grouted U_3O_8

	Scaling Factors	
Disposal Facility	Construction	Operations
Wasteform facility		
Grouted U_3O_8	1.00	0.62
Ungrouted U_3O_8	0.28	0.0041
Grouted UO_2	0.51	0.17
Ungrouted UO_2	0.17	0.0041
Shallow earthen structure		
Grouted U_3O_8	1.00	1.85
Ungrouted U_3O_8	0.51	0.87
Grouted UO_2	0.35	0.74
Ungrouted UO_2	0.26	0.56
Vault		
Grouted U_3O_8	1.00	2.87
Ungrouted U_3O_8	0.48	1.38
Grouted UO_2	0.21	1.12
Ungrouted UO_2	0.14	0.75

No quantitative estimate was made of the impacts on the ozone conditions. Ozone formation is a regional issue that would be affected by emissions for the entire area around a proposed disposal site. The pollutants most relevant to ozone formation that would result from the disposal of depleted uranium oxide are HC and NO_x. In later Phase II studies, when specific technologies and sites would be selected, the potential effects on ozone of releases of these pollutants at a proposed site could be evaluated by comparing those releases with the total emissions of HC and NO_x in the surrounding area. Small additional contributions to the regional totals would be unlikely to alter the ozone attainment status of the region.

I.3.4 Water and Soil

Tables I.20 through I.23 summarize the resource requirements for construction and operation of the wasteform facility, shallow earthen structure disposal facility, vault disposal facility, and mine disposal facility, respectively. Examination of these data indicates that the ranking of

TABLE 1.17 Maximum NO_x Concentrations at Three Receptor Distances from Construction of the Wasteform Facility and Operation of Vaults for Disposal of Grouted U_3O_8

	Maximum NO_x Concentrations ($\mu g/m^3$)				
Site Environment/ Receptor Distance	1-Hour Average	3-Hour Average	8-Hour Average	24-Hour Average	Annual Average
Wasteform Facility: Construction					
Dry setting					
750 m	160 – 170	59 – 70	27 – 37	11 – 14	1.3 – 2.3
1,000 m	130 – 140	51 – 61	22 – 29	8.4 – 11	0.82 – 1.5
1,500 m	92 – 96	29 – 35	14 – 19	5.5 – 6.9	0.43 – 0.80
Wet setting					
750 m	150 – 250	57 – 110	25 – 57	10 – 25	1.1 – 2.7
1,000 m	120 – 220	49 – 96	20 – 45	7.8 – 20	0.67 – 1.7
1,500 m	84 – 150	27 – 57	13 – 29	5.1 – 13	0.35 – 0.92
Vault for Grouted U_3O_8: Operations					
Dry setting					
750 m	590 – 980	220 – 470	100 – 260	41 – 110	4.6 – 21
1,000 m	480 – 730	190 – 310	84 – 170	32 – 65	2.9 – 8.5
1,500 m	330 – 450	110 – 160	52 – 96	20 – 37	1.5 – 3.0
Wet setting					
750 m	540 – 1,500	210 – 790	95 – 410	38 – 200	3.8 – 37
1,000 m	440 – 1,100	180 – 530	77 – 270	29 – 120	2.4 – 15
1,500 m	310 – 690	110 – 280	48 – 160	19 – 67	1.3 – 5.2

facilities (largest to smallest) on the basis of resource requirements would be as follows: mine, vault, shallow earthen structure, and wasteform facility. For each facility, a secondary ranking indicates that the resource requirements would be consistently larger for disposal of U_3O_8, and grouted forms would require more resources than ungrouted.

Because the disposal option is based on a generic site without a specified location and detailed description, impacts could not be assessed on a site-specific basis; however, the impacts to surface water, groundwater, and soil would follow the same ranking as that for resource needs. For example, construction and operation of a mine disposal facility for U_3O_8 in a grouted form would produce the greatest impacts to the environment; the least impacts would result from construction and operation of the shallow earthen structure for disposal of ungrouted UO_2.

TABLE I.18 Maximum NO_x Concentrations at Three Receptor Distances from Operation of the Shallow Earthen Structure for Disposal of Grouted U_3O_8

	Maximum NO_x Concentrations ($\mu g/m^3$)				
Site Environment/ Receptor Distance	1-Hour Average	3-Hour Average	8-Hour Average	24-Hour Average	Annual Average
Dry setting					
750 m	220 – 330	93 – 160	44 – 89	17 – 37	1.3 – 3.9
1,000 m	170 – 240	67 – 110	32 – 62	12 – 23	0.82 – 1.8
1,500 m	110 – 140	38 – 60	18 – 34	6.7 – 12	0.38 – 0.81
Wet setting					
750 m	200 – 510	90 – 260	41 – 140	16 – 67	1.1 – 6.8
1,000 m	160 – 370	64 – 180	30 – 100	11 – 40	0.68 – 3.2
1,500 m	97 – 220	37 – 100	17 – 55	6.6 – 22	0.35 – 1.3

If the disposal facility was located on a site having an area that was large compared with the size of the facility, and if it was near a river having a minimum flow that was large compared with annual water use and wastewater discharge, impacts to surface water, groundwater, and soil would be negligible. Negligible impacts would occur because a large site and large river could provide sufficient resource buffering to mitigate the effects produced by construction and operation of the facility.

On the other hand, if the site or the minimum flow in the river were small relative to the resource requirements, impacts would be larger. For example, if the minimum flow in the river was 500 gpm, the net annual water withdrawal for operation of the wasteform facility for disposing of grouted U_3O_8 would be about 10% of the flow. The impact of this relative withdrawal could produce moderate impacts to existing floodplains. Similarly, if the mine disposal facility were located on a 500-acre (200-ha) site, paving 94 acres (38 ha) for disposing of depleted uranium as grouted U_3O_8 would permanently alter the soil structure of almost 20% of the land available. This disruption could produce moderate to large impacts to runoff at the site and moderate to large impacts to soil permeability and erosion potential.

More detailed calculations would be performed in the next tier of analyses if a disposal facility option were selected. In general, impacts could be minimized by constructing and operating a facility that would have the smallest resource requirements.

TABLE I.19 Maximum Annual Average Uranium Concentrations in Air during Operation of the Wasteform Facility for Disposal of Grouted Uranium Oxide

Site Environment/ Receptor Distance	Maximum Annual Average Uranium Concentration ($\mu g/m^3$)
Disposal as Grouted UO_2	
Dry setting	
750 m	$1.7 \times 10^{-5} - 3.0 \times 10^{-5}$
1,000 m	$1.2 \times 10^{-5} - 2.1 \times 10^{-5}$
1,500 m	$0.71 \times 10^{-5} - 1.3 \times 10^{-5}$
Wet setting	
750 m	$1.8 \times 10^{-5} - 2.7 \times 10^{-5}$
1,000 m	$1.2 \times 10^{-5} - 2.0 \times 10^{-5}$
1,500 m	$0.76 \times 10^{-5} - 1.3 \times 10^{-5}$
Disposal as Grouted U_3O_8	
Dry setting	
750 m	$0.94 \times 10^{-5} - 1.6 \times 10^{-5}$
1,000 m	$0.66 \times 10^{-5} - 1.2 \times 10^{-5}$
1,500 m	$0.39 \times 10^{-5} - 0.72 \times 10^{-5}$
Wet setting	
750 m	$0.96 \times 10^{-5} - 1.5 \times 10^{-5}$
1,000 m	$0.68 \times 10^{-5} - 1.1 \times 10^{-5}$
1,500 m	$0.42 \times 10^{-5} - 0.70 \times 10^{-5}$

I.3.5 Socioeconomics

The socioeconomic impacts of each disposal option were assessed for a generic site because the location of a disposal facility has not yet been determined. Impacts for each facility are presented for the peak construction year and the first year of operations. Discussion of the assessment methodology is presented in Appendix C and Allison and Folga (1997). Table I.24 shows construction-related impacts (engineering, construction, project management, and site preparation and restoration activities), and operations-related impacts (operation, emplacement and closure, surveillance, and maintenance activities). Impacts for each facility are presented separately. Because the wasteform facility would be utilized to process waste at the disposal site for each disposal option,

TABLE I.20 Summary of Environmental Parameters for the Wasteform Facility

		Disposal as U_3O_8		Disposal as UO_2	
Parameter	Unit	Grouted	Ungrouted	Grouted	Ungrouted
Land area	acres	9.3	4	6.1	4
Disturbed area	acres	9.3	4	6.1	4
Paved area	acres	1.8	1	1.2	1
Water					
Construction	million gal/yr	1.1	0.3	0.7	0.2
Operations	million gal/yr	19.4	0.1	8.2	0.1
Wastewater					
Construction	million gal/yr	0.2	0.1	0.2	0.1
Operations	million gal/yr	1.1	0.1	0.6	0.1
Excavated material	yd^3	32,300	0	21,000	0

TABLE I.21 Summary of Environmental Parameters for the Shallow Earthen Structure Disposal Facility

		Disposal as U_3O_8		Disposal as UO_2	
Parameter	Unit	Grouted	Ungrouted	Grouted	Ungrouted
Land area	acres	76	42	33	24
Disturbed area	acres	70	38	29	20
Paved area	acres	2.7	2.0	1.7	1.5
Water					
Construction	million gal/yr	0.005	0.005	0.003	0.003
Operations	million gal/yr	0.02	0.01	0.01	0.01
Wastewater					
Construction	million gal/yr	0.005	0.005	0.003	0.003
Operations	million gal/yr	0.005	0.005	0.003	0.003
Excavated material	million yd^3	2.6	1.4	1.0	0.7

TABLE I.22 Summary of Environmental Parameters for the Vault Disposal Facility

		Disposal as U_3O_8		Disposal as UO_2	
Parameter	Unit	Grouted	Ungrouted	Grouted	Ungrouted
Land area	acres	140	71	35	24
Disturbed area	acres	140	71	35	24
Paved area	acres	19	11	5	4
Water					
Construction	million gal/yr	1.7	0.8	0.4	0.2
Operations	million gal/yr	0.05	0.02	0.02	0.01
Wastewater					
Construction	million gal/yr	0.04	0.02	0.008	0.005
Operations	million gal/yr	0.05	0.02	0.02	0.01
Excavated material	million yd^3	1.7	0.8	0.4	0.3

TABLE I.23 Summary of Environmental Parameters for the Mine Disposal Facility

		Disposal as U_3O_8		Disposal as UO_2	
Parameter	Unit	Grouted	Ungrouted	Grouted	Ungrouted
Land area	acres	462	228	143	98
Disturbed area	acres	462	228	143	98
Paved area	acres	94	46	29	20
Water					
Construction	million gal/yr	0.7	0.5	0.4	0.3
Operations	million gal/yr	0.9	0.6	0.5	0.4
Wastewater					
Construction	million gal/yr	0.2	0.07	0.2	0.07
Operations	million gal/yr	0.2	0.1	0.08	0.07
Excavated material	million yd^3	2	1.2	0.9	0.4

the total impact of each option would be the summation of the impacts of the wasteform facility and the impact of each separate option.

I.3.5.1 Disposal as U_3O_8

The impacts of U_3O_8 disposal options in both grouted and ungrouted form on direct employment and income are shown in Table I.24. Construction of a wasteform facility for grouted U_3O_8 would create 360 direct jobs and $15 million in direct income during the peak year of construction in 2006. Operation of the grouted U_3O_8 wasteform facility would create 90 direct jobs and produce $13 million in direct income with the beginning of facility operations in 2009. Construction of a wasteform facility for ungrouted U_3O_8 would create 110 direct jobs and $4 million in direct income during the peak year of construction in 2006. Operation of the ungrouted U_3O_8 wasteform facility would create 40 direct jobs and produce $5 million in direct income annually with the beginning of facility operations in 2009.

Construction of a shallow earthen structure for grouted U_3O_8 would create 10 direct jobs and $1 million in direct income during the peak year of construction in 2008. Waste placement operations for a shallow earthen structure for grouted U_3O_8 would create 50 direct jobs and produce $3 million in direct income annually with the beginning of facility operations in 2009. Construction of a shallow earthen structure for ungrouted U_3O_8 would create less than 5 direct jobs and less than $500,000 in direct income during the peak year of construction in 2008. Operation of a shallow earthen structure for ungrouted U_3O_8 would create 30 direct jobs and produce $2 million in direct income annually with the beginning of facility operations in 2009.

Construction of a vault facility for grouted U_3O_8 would create 180 direct jobs and $8 million in direct income during the peak year of construction in 2008. Waste placement operations for a vault facility for grouted U_3O_8 would create 190 direct jobs and produce $5 million in direct income annually with the beginning of facility operations in 2009. Construction of a vault facility for ungrouted U_3O_8 would create 90 direct jobs and $4 million in direct income during the peak year of construction in 2008. Operation of a vault facility for ungrouted U_3O_8 would create 40 direct jobs and produce $3 million in direct income annually with the beginning of facility operations in 2009.

Construction of a mine facility for grouted U_3O_8 would create 410 direct jobs and $27 million in direct income during the peak year of construction in 2005. Waste placement operations for a mine facility for grouted U_3O_8 would create 190 direct jobs and produce $3 million in direct income annually with the beginning of facility operations in 2009. Construction of a mine facility for ungrouted U_3O_8 would create 300 direct jobs and $20 million in direct income during the peak year of construction in 2005. Operation of a mine facility for ungrouted U_3O_8 would create 30 direct jobs and produce $2 million in direct income with the beginning of facility operations in 2009.

TABLE I.24 Socioeconomic Impacts of U_3O_8 and UO_2 Disposal Facilities

	Disposal of Grouted Form		Disposal of Ungrouted Form	
Option/Location/Activity	Construction[a]	Operations[b]	Construction[a]	Operations[b]
U_3O_8 Disposal Facility				
Wasteform facility				
Direct employment	360	90	110	40
Direct income ($ million 1996)	15	13	4	5
Shallow earthen structure				
Direct employment	10	50	< 5	30
Direct income ($ million 1996)	1	3	< 0.5	2
Vault				
Direct employment	180	90	90	40
Direct income ($ million 1996)	8	5	4	3
Mine				
Direct employment	410	40	300	30
Direct income ($ million 1996)	27	3	20	2
UO_2 Disposal Facility				
Wasteform facility				
Direct employment	220	90	60	40
Direct income ($ million 1996)	9	12	3	5
Shallow earthen structure				
Direct employment	< 5	30	< 5	20
Direct income ($ million 1996)	< 0.5	1	< 0.5	1
Vault				
Direct employment	50	40	30	30
Direct income ($ million 1996)	2	2	1	2
Mine				
Direct employment	270	40	250	30
Direct income ($ million 1996)	18	2	16	2

[a] Impacts in the peak year of construction: 2007 for the wasteform facility; 2009 for the shallow earthen structure and the vault; and 2006 for the mine. Preoperations were assumed to occur from 1999 through 2008, with construction continuing concurrently with waste placement through 2028.

[b] Impacts are the annual average for operations for the period 2009–2028 (20 years).

I.3.5.2 Disposal as UO_2

The impacts of UO_2 disposal options in both grouted and ungrouted form on direct employment and income are shown in Table I.24. Construction of a wasteform facility for grouted UO_2 would create 220 direct jobs and \$9 million in direct income during the peak year of construction in 2006. Operation of the grouted UO_2 wasteform facility would create 90 direct jobs and produce \$12 million in direct income annually with the beginning of facility operations in 2009. Construction of a wasteform facility for ungrouted UO_2 would create 60 direct jobs and \$3 million in direct income during the peak year of construction in 2006. Operation of the ungrouted UO_2 wasteform facility would create 40 direct jobs and produce \$5 million in direct income annually with the beginning of facility operations in 2009.

Construction of a shallow earthen structure for grouted UO_2 would create less than 5 direct jobs and less than \$500,000 in direct income during the peak year of construction in 2008. Waste placement operations for a shallow earthen structure for grouted UO_2 would create 30 direct jobs and produce \$1 million in direct income annually with the beginning of facility operations in 2009. Construction of a shallow earthen structure for ungrouted UO_2 would create less than 5 direct jobs and less than \$500,000 in direct income during the peak year of construction in 2008. Operation of a shallow earthen structure for ungrouted UO_2 would create 20 direct jobs and produce \$1 million in direct income annually with the beginning of facility operations in 2009.

Construction of a vault facility for grouted UO_2 would create 50 direct jobs and \$2 million in direct income during the peak year of construction in 2005. Waste placement operations for a vault facility for grouted UO_2 would create 40 direct jobs and produce \$2 million in direct income annually with the beginning of facility operations in 2009. Construction of a vault facility for ungrouted UO_2 would create 30 direct jobs and \$1 million in direct income during the peak year of construction in 2005. Operation of a vault facility for ungrouted UO_2 would create 30 direct jobs and produce \$2 million in direct income with the beginning of facility operations in 2009.

Construction of a mine facility for grouted UO_2 would create 270 direct jobs and \$18 million in direct income during the peak year of construction in 2005. Waste placement operations for a mine facility for grouted UO_2 would create 40 direct jobs and produce \$2 million in direct income annually with the beginning of operations in 2009. Construction of a mine facility for ungrouted UO_2 would create 250 direct jobs and \$16 million in direct income during the peak year of construction in 2005. Operation of a mine facility for ungrouted UO_2 would create 30 direct jobs and produce \$2 million in direct income annually with the beginning of facility operations in 2009.

I.3.6 Ecology

Moderate to large impacts to ecological resources could result from construction of a facility for disposal of U_3O_8 or UO_2. Impacts could include mortality of individual organisms, habitat loss, or changes in biotic communities. Discussion of the methodology used to assess ecological impacts is presented in Appendix C.

I.3.6.1 Disposal as U_3O_8

I.3.6.1.1 Shallow Earthen Structure

Site preparation for the construction of a facility for the disposal of U_3O_8 in shallow earthen structures would require the elimination of approximately 46 acres (18 ha) of habitat for ungrouted U_3O_8 and 85 acres (34 ha) for grouted U_3O_8, including 3 acres (1.1 ha) that would be paved — including the areas required for construction of the wasteform facility, primarily structures and paved areas. Existing vegetation would be destroyed during land clearing activities. The vegetative communities that would be eliminated by site preparation would depend on the actual location of the facility. Although herbaceous vegetation could be reestablished relatively rapidly in a wet setting (with at least 40 in./yr [100 cm/yr] precipitation), such as in the eastern United States, a considerable period of time might be required in a dry setting (less than 10 in./yr [25 cm/yr] precipitation), such as in the western United States. The loss of 46 to 85 acres (18 to 34 ha) of undeveloped land would constitute a moderate adverse impact to vegetation. Erosion of exposed soil at construction sites could reduce the effectiveness of restoration efforts and create sedimentation downgradient of the site. The implementation of standard erosion control measures, installation of storm-water retention ponds, and immediate replanting of disturbed areas with native species would help minimize impacts to vegetation. Impacts due to facility construction are shown in Table I.25.

Wildlife would be disturbed by land clearing, noise, and human presence. Wildlife with restricted mobility, such as burrowing species or juveniles of nesting species, would be destroyed during land clearing activities. Mobile individuals would relocate to adjacent available areas with suitable habitat. Population densities and competition would increase in these areas, potentially reducing the chances of survival or reproductive capacity of displaced individuals. Some wildlife species would be expected to recolonize replanted areas near the disposal facility following completion of construction. However, habitat use in the vicinity of the facility might be reduced for some species due to the construction of a perimeter fence. Therefore, the loss of 85 acres (34 ha) of habitat for the construction of a facility for U_3O_8 disposal in shallow earthen structures would be considered a moderate adverse impact to wildlife.

Wetlands could potentially be impacted by filling or draining during construction. In addition, impacts to wetlands and aquatic habitats due to alteration of surface water runoff patterns, soil compaction, or groundwater flow could occur if the disposal facility was located adjacent to wetland or aquatic areas. However, impacts would be minimized by maintaining a buffer area around wetlands and aquatic habitats during construction of the facility. Unavoidable impacts to wetlands would require a *Clean Water Act* Section 404 permit, which might stipulate mitigative measures. Additional permitting might be required by state agencies. Depending on the facility location, water

TABLE I.25 Impacts to Ecological Resources from Disposal Facility Construction

Option/ Resource	Impacts from Disposal Facility Construction[a] Shallow Earthen Structure	Vault	Mine
Disposal as U_3O_8			
Vegetation	Loss of 46 to 85 acres Moderate adverse impact	Loss of 75 to 149 acres Moderate to large adverse impact	Loss of 232 to 471 acres Large adverse impact
Wildlife	Loss of 46 to 85 acres Moderate adverse impact	Loss of 75 to 149 acres Moderate to large adverse impact	Loss of 232 to 471 acres Large adverse impact
Aquatic	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat
Wetlands	Potential loss, degradation	Potential loss, degradation	Potential loss, degradation
Protected species	Potential destruction, habitat loss	Potential destruction, habitat loss	Potential destruction, habitat loss
Disposal as UO_2			
Vegetation	Loss of 28 to 39 acres Moderate adverse impact	Loss of 28 to 41 acres Moderate adverse impact	Loss of 102 to 149 acres Large adverse impact
Wildlife	Loss of 28 to 39 acres Moderate adverse impact	Loss of 28 to 41 acres Moderate adverse impact	Loss of 102 to 149 acres Large adverse impact
Aquatic	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat	Potential reduction in water quality, habitat
Wetlands	Potential loss, degradation	Potential loss, degradation	Potential loss, degradation
Protected species	Potential destruction, habitat loss	Potential destruction, habitat loss	Potential destruction, habitat loss

[a] All acreages include the wasteform facility.

withdrawal from surface waters or groundwater, as well as wastewater discharge, could potentially alter water levels (Section I.3.4), which could in turn affect aquatic ecosystems, including wetlands, especially those located along the periphery of these surface water bodies.

Prior to construction of a disposal facility, a survey for state and federally listed threatened, endangered, or candidate species, or species of special concern would be conducted so that, if possible, impacts to these species could be avoided. Where impacts were unavoidable, appropriate mitigation could be developed.

Ecological resources in the vicinity of the wasteform facility would be exposed to atmospheric emissions from facility operation; however, emission levels would be expected to be extremely low (Section I.3.3). At 230 ft (750 m) away, the highest annual average air concentration of U_3O_8 due to operation of the facility would be 1.6×10^{-5} µg/m³. Resulting impacts to biota would be negligible.

Facility accidents, as discussed in Section I.3.2, could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors, such as location of the accident, season, and meteorological conditions.

I.3.6.1.2 Vault

The construction and operation of a facility for the disposal of U_3O_8 in vaults would generally result in impacts similar to those associated with shallow earthen structures. However, the size of the facility and area of disturbance for vault disposal would be larger. Disposal in vaults would require the disturbance of approximately 75 to 149 acres (30 to 60 ha) of habitat and 19 acres (8 ha) for paved areas, including the wasteform facility for grouted U_3O_8. This disposal option would also result in elevation of the soil surface by placement of excavated material and in reduction in soil permeability. The consequent decrease in soil moisture would make reestablishment of vegetation difficult and delay the establishment of native plant communities. This disposal option would result in a moderate to large adverse impact to existing vegetation and wildlife. Reestablishment of native vegetation over such a large area would be especially difficult in a dry environmental setting, and a considerable period of time might be required.

I.3.6.1.3 Mine

The construction and operation of a facility for the disposal of U_3O_8 in a mine would generally result in impacts similar to those associated with vaults. However, the mine option would require the disturbance of approximately 232 to 471 acres (93 to 188 ha), including 104 acres (42 ha) for buildings, paved areas, and the wasteform facility for grouted U_3O_8. This disposal option would result in elevation of the soil surface and in reduction in soil permeability. The excavated material would primarily consist of rock removed from the drifts and ramps. The consequent decrease in surface soil moisture would make reestablishment of vegetation difficult and delay the establishment of native plant communities. This disposal option would result in a large adverse impact to existing vegetation and wildlife. Reestablishment of native vegetation over such a large area would be especially difficult in a generic dry western environmental setting, and a considerable period of time might be required.

I.3.6.2 Disposal as UO_2

The construction and operation of a facility for the disposal of UO_2 would generally result in the types of impacts associated with the disposal of U_3O_8; however, the facility sizes would be smaller. A facility for disposal of UO_2 in shallow earthen structures would eliminate approximately 28 to 39 acres (11 to 16 ha) of habitat, including the wasteform facility for grouted UO_2. This habitat loss would result in a moderate adverse impact to vegetation and wildlife. A facility for the disposal of UO_2 in vaults would eliminate approximately 28 to 41 acres (11 to 16 ha) of habitat, including the wasteform facility for grouted UO_2. This loss would result in a moderate adverse impact to vegetation and wildlife. A mine disposal facility for UO_2 would result in disturbance of approximately 102 to 149 acres (41 to 60 ha) of habitat, including the wasteform facility for grouted UO_2. This habitat disturbance would constitute a large adverse impact to vegetation and wildlife.

Atmospheric emissions from wasteform facility operations would be expected to be slightly lower for grouted UO_2 disposal than for grouted U_3O_8 disposal (Section I.3.3). Emissions would be similar for ungrouted UO_2 and U_3O_8 disposal. The highest annual average air concentration of UO_2, due to operation of the facility, would be 0.00003 $\mu g/m^3$ at a distance of 230 ft (750 m) away from the facility. Resulting impacts to biota would be negligible.

I.3.7 Waste Management

Wastes would be generated during the construction of the wasteform facility. This facility would be used for the receipt of waste, grouting of the uranium oxide (if necessary), and storage of both the input and output from the facility. Waste generation would also occur during the construction of any of the three types of disposal facilities. No radioactive wastes would be generated during construction of the wasteform facility or any of the three possible disposal facilities because no radioactive materials would be used and the site would be uncontaminated. Table I.26 lists the various hazardous materials that would be generated in construction of the different types of disposal facilities. Only small differences are expected for the generation of waste for these different disposal options. The waste generated in the construction of any of these disposal facilities represents a negligible impact to DOE's waste management capabilities.

In grouting the converted uranium oxide, operation of the wasteform facility would generate two waste streams: the product (final form of uranium oxide grout) and minor amounts of secondary waste associated with making the final grout product of uranium. Table I.27 lists the volume throughputs of this facility as a function of the four different final form options for uranium. For the ungrouted wasteforms of U_3O_8 and UO_2, this facility would be used only as temporary storage between the conversion and disposal facilities. Consequently, no secondary waste streams would be generated at this facility for the ungrouted U_3O_8 and UO_2 final form options. Table I.28 lists the annual operational wastes from the wasteform facility for each of the four final waste form options (product waste) as well as the secondary waste streams expected from the two grouted waste options. The initial volumes of U_3O_8 and UO_2 listed under facility waste in Table I.28 are equivalent to the

TABLE I.26 Estimated Construction Wastes Generated under the Disposal Options

	U_3O_8 (m^3)		UO_2 (m^3)	
Facility/Waste Type	Grouted	Ungrouted	Grouted	Ungrouted
Wasteform Facility				
Hazardous liquids				
Paints	6.4	2.6	2.2	0.9
Phenol	1.6	0.6	0.6	0.2
Sulfuric acid	0.8	0.3	0.3	0.1
Total	8.8	3.5	3.1	1.2
Hazardous solids				
Mercury lamps	0.8	0.3	0.3	0.1
Lead batteries	0.2	0.1	0.1	0.05
Nonhazardous solids				
Conventional waste	600	240	210	90
Shallow Earthen Structure				
Hazardous liquids				
Paints	1.6	0.6	0.6	0.2
Phenol	0.4	0.2	0.1	0.05
Sulfuric acid	0.2	0.1	0.1	0.05
Total	2.2	0.9	0.8	0.3
Hazardous solids				
Mercury lamps	0.2	0.1	0.1	0.05
Lead batteries	0.05	0.03	0.02	0.01
Nonhazardous solids				
Conventional waste	150	60	60	30
Vault				
Hazardous liquids				
Paints	3.2	1.3	1.1	0.4
Phenol	0.8	0.3	0.3	0.1
Sulfuric acid	0.4	0.2	0.1	0.1
Total	4.4	1.8	1.5	0.6
Hazardous solids				
Mercury lamps	0.4	0.2	0.2	0.1
Lead batteries	0.1	0.04	0.03	0.01
Nonhazardous solids				
Conventional waste	300	120	110	50
Mine				
Hazardous liquids				
Paints	9.6	3.8	3.4	1.4
Phenol	2.4	1.0	0.8	0.3
Sulfuric acid	1.2	0.5	0.4	0.2
Total	13.2	5.3	4.6	1.9
Hazardous solids				
Mercury lamps	16.0	11.2	9.0	7.4
Lead batteries	0.4	0.3	0.2	0.15
Nonhazardous solids				
Conventional waste	900	640	500	420

TABLE I.27 Variations in Wasteform Facility Operations for the Different Final Forms of Uranium

Uranium Type	Throughput Quantity (m^3)	Containers Number	Containers Type
Grouted U_3O_8	312,000	1,560,000	55-gal
Ungrouted U_3O_8	148,800	714,000	55-gal
Grouted UO_2	72,000	630,000	30-gal
Ungrouted UO_2	47,600	420,000	30-gal

final waste volumes expected for the two ungrouted wasteforms because no waste processing would take place in this facility for these two options.

Estimates of the amount of LLW to be disposed of at DOE waste management disposal facilities depend critically upon the time frame under consideration and the types of waste to be included. The *Waste Management Programmatic Environmental Impact Statement* (WM PEIS) estimates that 1,060,000 m^3 of LLW will be disposed of during the time frame 1995-2014 (DOE 1997). This estimate does not include any LLW from environmental restoration activities or facility stabilization activities. A more appropriate value is reported in *The 1996 Baseline Environmental Management Report* (BEMR) (DOE 1996), which estimates the total amount of LLW for treatment at waste management facilities to be 3,400,000 m^3. This estimate is for the next 75 years and includes contributions from environmental restoration and facility stabilization programs.

The majority of environmental restoration wastes are expected to be generated between 2003 and 2033, approximately the correct time frame to compare with the depleted UF_6 program. For this reason, the BEMR estimate was used for comparison with the depleted UF_6 wastes. Adjustments must be made to the BEMR estimate to convert treatment volumes into disposal volumes. Both volume reductions and expansions would occur during waste treatment and grouting, depending on the relative amounts of the different types of waste. On the basis of the WM PEIS analysis (DOE 1997), the BEMR estimate was adjusted to 4,250,000 m^3 for the estimated disposal volume. The total LLW disposal volumes from disposal of depleted uranium, as either UO_2 or U_3O_8 (grouted or ungrouted), were compared with the total estimated disposal volume for LLW for all DOE waste management activities (including environmental restoration waste). Disposal volumes were compared as total volume (m^3) because disposal facilities would typically have no throughput limitations but rather would be limited by the total volume of waste that could be accepted.

For the case of grouted U_3O_8 with a waste volume of 15,600 m^3/yr, the total disposal volume would be [(15,600) × 20 years operation] = 312,000 m^3. This would add about 7.3% to the estimated total DOE LLW disposal volume of about 4,250,000 m^3. Using a similar approach for the other cases would add about 1.7% for grouted UO_2, 3.5% for ungrouted U_3O_8, and 1.1% for

TABLE I.28 Estimated Annual Radioactive Waste Streams from Wasteform Facility Operations

Waste Stream	Treatment	Initial Volume (m^3/yr)		Final Volume (m^3/yr)		Uranium Content (kg)	Treatability Category
		Ungrouted U_3O_8	Ungrouted UO_2	Grouted U_3O_8	Grouted UO_2		
Facility waste (product)	Cement solidification	7,440	2,380	15,600	3,600	18,900,000[a]	Not applicable
HEPA filters	Drumming	24	24	24	24	5.7[b]	Noncombustible compactible solid (LLW)
Dry active waste	Dewater/Drum	57	24	24	5.5	760[b]	Combustible solid (LLW)
Inorganic spray solution used to clean drums	Neutralize	0.31	0.2	0.18	0.10	< 1	Low-level mixed waste
Cotton waste wipes used to clean drums[c]	Neutralize	NA	NA	0.0078 m^3 (5 kg)	0.0078 m^3 (5 kg)	< 1	Low-level mixed waste

[a] Uranium content determined by stoichiometry, given in the form of U_3O_8.

[b] Determined by analogy to production facilities.

[c] Final volume based on bulk density of 40 lb/ft^3.

ungrouted UO_2 to the total volume. The amount of low-level mixed waste (LLMW) from depleted UF_6 disposal added to total nationwide LLMW load would be negligible (less than 1%).

Although more secondary wastes would be generated in producing either of the grouted wasteforms of U_3O_8 and UO_2, compared with the ungrouted wasteforms, the differences are not significant. The choice of which wasteform would be used should be based on other factors such as long-term stability of the wasteform, leach rates of the radioactive contaminants, and cost.

Waste generation for the different disposal options is not expected to vary with wet or dry environments. The choice of which disposal option would be used in a wet or dry environment is based on considerations other than waste generation.

Overall, the disposal options would generate appreciable amounts of waste for disposal in DOE facilities. Within the context of the total amount of LLW undergoing disposal in DOE facilities, these wastes would have a low impact on DOE's total waste management disposal capabilities.

I.3.8 Resource Requirements

Resource requirements for the disposal options were estimated for construction and operations. The materials required for monitoring of the groundwater and disposal cell performance would be expected to be minor.

Materials and utilities required for construction and operation of the shallow earthen structure, vault, and mine options are presented in Table I.29. In general, the amount of resources is directly related to the volume of waste to be disposed, with the greatest resources required for the grouted U_3O_8 waste form and least with the ungrouted UO_2 waste form. A fixed facility for solidification is required for the two grouted waste forms, which results in greater construction requirements. During the operations phase, cement and sand are required for solidification of the uranium oxides. The total quantities of commonly used construction materials are not expected to be significant and would be comparable to construction of a multistory building. No specialty materials (e.g., Monel or Inconel) are projected to be needed for either construction or operations phases.

Significant quantities of electrical energy could be required during construction of the mine option because most of the construction equipment utilized in underground mines is powered by electricity to avoid polluting the air in the underground work area. Similarly, a relatively higher annual consumption of electricity is projected during underground operations, compared with the other disposal facility options.

TABLE I.29 Resource Requirements for Construction and Operation of Disposal Facilities

			Resource Requirements for Disposal Facility			
Facility/Activity	Resource	Unit	Grouted U_3O_8	Ungrouted U_3O_8	Grouted UO_2	Ungrouted UO_2
Shallow Earthen Structure						
Construction	Utilities					
	Electricity	MWh	7,700	4,000	3,100	2,300
	Solids					
	Concrete	yd^3	20,000	5,400	10,000	3,200
	Sand	yd^3	124,000	59,400	37,000	25,400
	Steel	tons	1,000	300	600	200
	Liquids					
	Diesel fuel	gal	530,000	260,000	200,000	130,000
Operations	Utilities					
	Electricity	MWh/yr	3,200	1,300	1,800	1,000
	Liquids					
	Diesel fuel	gal/yr	64,000	21,000	23,000	13,000
	Gases					
	Natural gas	million scf/yr	14	5.3	14	5.3
Vault						
Construction	Utilities					
	Electricity	MWh	3,100	1,400	1,000	590
	Solids					
	Concrete	yd^3	410,000	190,000	90,000	56,000
	Sand	yd^3	0	0	0	0
	Steel	tons	10,000	6,000	3,000	2,000
	Liquids					
	Diesel fuel	gal	860,000	400,000	200,000	120,000
Operations	Utilities					
	Electricity	MWh/yr	4,900	2,600	2,500	1,100
	Liquids					
	Diesel fuel	gal/yr	130,000	55,000	50,000	30,000
	Gases					
	Natural gas	million scf/yr	14	5.3	14	5.3

TABLE I.29 (Cont.)

			Resource Requirements for Disposal Facility			
Facility/Activity	Resource	Unit	Grouted U_3O_8	Ungrouted U_3O_8	Grouted UO_2	Ungrouted UO_2
Mine						
Construction	Utilities					
	Electricity	million MWh[a]	10	4.3	2.8	1.9
	Solids					
	Concrete	yd^3	180,000	102,000	83,000	62,000
	Sand	yd^3	0	0	0	0
	Steel	tons	42,000	17,000	18,000	8,900
	Liquids					
	Diesel fuel	gal	300,000	150,000	130,000	90,000
Operations	Utilities					
	Electricity	MWh/yr	110,900	6,600	5,900	4,300
	Liquids					
	Diesel fuel	gal/yr	23,000	2,000	8,000	2,000
	Gases					
	Natural gas	million scf/yr	14	5.3	14	5.3

[a] For the mine disposal facility, the unit of electricity is million MWh compared with MWh for the other disposal options.

I.3.9 Land Use

Land area requirements for each disposal option are presented in Table I.30. These data do not include acreage required for the construction phase for any of the disposal options because development of land would be incremental and space required for material excavation storage, equipment staging, and construction material laydown areas would be available on adjacent undeveloped parcels. Consequently, areal needs for construction would not be greater than those for operations.

Although no site has been chosen for facilities under each disposal option, selection of a site at or near a location that is already dedicated to similar use could result in reduced land-use impacts because immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land use.

All disposal options would include a central wasteform facility where drums of uranium oxide would be received from the conversion facility and prepared for disposal. The facility would

TABLE I.30 Land Requirements and Excavated Material Volumes for Disposal Facilities

	Land Requirement[a] (acres)			
	Disposal as U_3O_8		Disposal as UO_2	
Facility	Grouted	Ungrouted	Grouted	Ungrouted
Shallow earthen structure	85	46	39	28
Vault	149	75	41	28
Mine	471	232	149	102

[a] Values include the wasteform facility areas, as follows: grouted U_3O_8 options, 9 acres, ungrouted U_3O_8 options, 4 acres; grouted UO_2 options, 6 acres; ungrouted UO_2 options, 4 acres.

Source: LLNL (1997).

include a grouting/cementing building, if necessary, which could affect the number of buildings erected for the wasteform facility. Impacts to land use from the wasteform facility would be very small and limited to clearing of required land, as well as potential minor and temporary disruptions to contiguous land parcels. No off-site impacts would be expected.

Land-use impacts resulting from the shallow earthen structure disposal option would be negligible to moderate and limited to clearing of required land and a potential slight increase in off-site vehicular traffic associated with construction activities. The shallow earthen structure option would require from 28 to 85 acres (11 to 34 ha) of land (including the wasteform facility) that would be cleared and developed incrementally. The rate of development would be determined by the selection of the wasteform. Up to 2.62 million yd^3 (2.0 million m^3) would be excavated. The large volume of excavated material that would remain on-site could, over time, result in topographical modifications of the site. Impacts of off-site disposal would be determined during the site-specific tier of NEPA documentation. Other than minor, temporary impacts associated with construction traffic, no other off-site impacts would be expected.

The vault option would require from 28 to 149 acres (11 to 60 ha) of land and would result in up to 1.62 million yd^3 (1.27 million m^3) of excavated material. Because the vault facility would be constructed incrementally (10 vault blocks per year), the amount of land disturbed during a given year would be limited. Impacts of off-site disposal would be determined during the site-specific tier of NEPA documentation.

Of all the disposal options, a mine would have the greatest potential for land-use impacts. A mine would require the largest amount of land, 102 to 471 acres (41 to 188 ha) (see Table I.30).

The construction associated with this option could result in potential land disturbance impacts for adjacent parcels. The large volume of excavated material (1.96 million yd^3 [1.5 million m^3]) would be disposed of on-site, probably resulting in topographical modifications of the site. The peak construction labor force could result in off-site land-use impacts, particularly if a remote site were chosen. Impacts could include pressure on existing commercial land and traffic congestion on local access roads and intersections.

I.3.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur if the disposal options considered in this PEIS were implemented include impacts to cultural resources and environmental justice, as well as impacts to the visual environment (e.g., aesthetics), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of the disposal facilities. These impacts, although considered, were not analyzed in detail for one or more of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier NEPA documentation when specific sites are considered.

- Consideration of these impacts would not contribute to differentiation among the alternatives and, therefore, would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

I.4 IMPACTS OF OPTIONS — POST-CLOSURE PHASE

This section provides a summary of the potential environmental impacts associated with the post-closure phase of the disposal options. The post-closure phase considers the potential environmental impacts that could occur in the future, well beyond the time that any engineered disposal facility would be expected to function as designed. Post-closure impacts are evaluated because, no matter how well designed, all disposal facilities would be expected to release material to the environment eventually, a condition referred to as "failure."

Disposal facility failure would generally occur hundreds to thousands of years in the future (assuming no sustained effort to maintain the facility). This failure would be caused by natural degradation of the disposal structures over time, primarily from physical processes such as the intrusion of water. Following failure, the release of uranium from the facility would occur very slowly as water moved through the disposed material. This water would carry dissolved uranium through the soil under the facility, eventually contaminating the groundwater. This process could continue for thousands to millions of years because of the large amount of uranium in the disposal facility and low solubility of that uranium.

In general, shallow earthen structures would be expected to contain the waste material for a period of at least several hundred years before failure. Vaults and a mine would be expected to last even longer, from many hundreds to thousands of years before failure. However, the exact time that a disposal facility would be expected to fail is extremely difficult to predict and would depend on the detailed facility design and site-specific conditions. Because of this difficulty, failure was assumed to occur at the end of a period of institutional control, 100 years after closure. The post-closure impacts were evaluated at 1,000 years after failure for all three disposal facility options.

Post-closure impacts were evaluated in three areas: (1) potential impacts to groundwater, (2) potential impacts to human health and safety, and (3) potential impacts to ecological resources. Impacts in other areas would be expected to be negligible. The following general assumptions apply to the assessment of post-closure impacts:

- All disposal facilities would fail at some time in the future. Failure is defined as the release of uranium material from the disposal facility to the surrounding soil. For consistency, failure was assumed to occur at the end of institutional control, 100 years after closure.

- The post-closure phase primarily considers impacts from the potential contamination of groundwater and surface water. Potential impacts from contamination of air and soil due to erosion of the disposal facility surface are also discussed.

- Impacts were evaluated at a time of 1,000 years after the facility failed and started to release uranium.

- Two generic environmental settings were assumed for the disposal facilities: a dry setting and a wet setting (see Section 3.4.4 for details).

- For analysis of groundwater impacts, assumptions were varied to assess a broad range of possibilities with respect to movement of the uranium through the soil to the groundwater aquifer.

The estimated impacts associated with the post-closure phase are subject to a great deal of uncertainty because the assessment considers an extremely long period of time and depends on predicting the behavior of the waste material as it interacts with soil and water in a complex and changing environment. Consequently, the estimated impacts are very dependent on the assessment assumptions. Key assumptions include such factors as soil characteristics, water infiltration rates, depth to the underlying groundwater table, chemistry of different uranium compounds, and the locations of future human receptors. These factors can vary widely depending on site-specific conditions. Because of these uncertainties, the assumptions were generally selected in a manner intended to produce conservative estimates of impact, that is, the assumptions tend to overestimate the expected impact. Changes in key disposal assumptions could yield significantly different estimates of impact.

I.4.1 Human Health — Normal Operations

I.4.1.1 Radiological Impacts

Radiation doses and cancer risks for the post-closure phase were assessed for a hypothetical individual who would live at or near the disposal site after the institutional control period of the site ended. This individual was assumed to drill a well at the edge of the disposal site and use the well water for drinking, household purposes, irrigating plant foods and fodder, and watering livestock. Because of leaching of uranium from the disposal area to the groundwater table, the hypothetical resident could be exposed to radiation through use of contaminated well water. Detailed discussions of the methodologies used in radiological impact analyses are provided in Cheng et al. (1997). Additional information on the methodology and assumptions used in the groundwater analyses is provided in Section I.4.2.

The estimated groundwater concentrations involve large degrees of uncertainty because of the preliminary nature of facility design and the various soil properties that depend on the location of the facility. The radiological impacts estimated by using the groundwater concentrations are subject to a large degree of uncertainty as well. The groundwater contamination would persist for millions of years once it occurred because of the large inventory of U_3O_8 and UO_2 in the disposal area. Because of the long decay half-lives of uranium isotopes and the continuous generation of decay products, the maximum radiation dose, which could be greater than 1 rem/yr from using contaminated groundwater, would not be observed until sometime after 10,000 years, a time frame well beyond that considered in this analysis. Table I.31 lists the calculated radiation doses and cancer risks for the maximally exposed individual (MEI) 1,000 years after the failure of engineering barriers and waste containers. Although impacts from using the contaminated groundwater at that time could reach 110 mrem/yr, they could be either minimized by treating the groundwater or eliminated by switching to a clean water source.

In addition to the possible exposures resulting from use of contaminated groundwater, radiological impacts could be caused by external radiation and inhalation of contaminated dust particles if all the cover materials above the disposal site were removed and if containers of U_3O_8 or UO_2 disintegrated. This scenario could be caused by natural forces of erosion over long periods of time or by human intervention (i.e., digging) to bring the waste to the surface. The associated external radiation dose could be as high as 10 rem/yr for an individual living on the disposal site. However, the exposure would not occur until several thousand years after closure of the shallow earthen structure or vault disposal facility and would be quite unlikely for mine disposal because a mine would be located at a depth of several hundred feet below the ground surface. Detailed analyses for this exposure scenario were not conducted because it is beyond the time frame considered in this

TABLE I.31 Human Health Impacts for the MEI from Disposal Options: Post-Closure Phase

	Radiological Impacts at 1,000 Years[b,c]				Chemical Impacts at 1,000 Years[b,c]	
	MEI Dose (mrem/yr)		MEI Risk (LCF/yr)		MEI Hazard Index[d]	
Option/ Location[a]	Grouted Oxide	Ungrouted Oxide	Grouted Oxide	Ungrouted Oxide	Grouted Oxide	Ungrouted Oxide
Disposal as U_3O_8						
Shallow earthen structure						
Dry	0	0	0	0	0	0
Wet	49 – 72	41 – 60	2×10^{-5} – 4×10^{-5}	2×10^{-5} – 3×10^{-5}	5.9 – 8.7	5.0 – 7.3
Vault						
Dry	0	0	0	0	0	0
Wet	57 – 84	48 – 70	3×10^{-5} – 4×10^{-5}	2×10^{-5} – 4×10^{-5}	6.9 – 10	5.8 – 8.5
Mine						
Dry	0	0	0	0	0	0
Wet	0.88 – 110	0.72 – 93	4×10^{-7} – 6×10^{-5}	4×10^{-7} – 5×10^{-5}	0.1 – 14	0.1 – 11
Disposal as UO_2						
Shallow earthen structure						
Dry	0	0	0	0	0	0
Wet	37 – 54	34 – 50	2×10^{-5} – 3×10^{-5}	2×10^{-5} – 3×10^{-5}.	4.5 – 6.6	4.1 – 6.0
Vault						
Dry	0	0	0	0	0	0
Wet	38 – 56	34 – 50	2×10^{-5} – 3×10^{-5}	2×10^{-5} – 3×10^{-5}	4.6 – 6.7	4.2 – 6.1
Mine						
Dry	0	0	0	0	0	0
Wet	0.64 – 84	0.59 – 77	3×10^{-7} – 4×10^{-5}	2×10^{-7} – 4×10^{-5}	0.1 – 10	0.1 – 9.3

[a] Two generic environmental settings were considered for each option, corresponding to dry and wet environments, respectively.

[b] Impacts are reported as ranges, which result from different transport speeds of radionuclides in the unsaturated and saturated zones. Retardation factors of 5 and 50 were used to represent relatively mobile and immobile transport situations, respectively. Values correspond to estimated impacts 1,000 years after failure of the engineering barriers and containers.

[c] The maximally exposed individual was assumed to live at the edge of the disposal site and use contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. The exposure pathways considered were ingestion of drinking water, plant foods, meat, and milk; and, for radiological exposures, inhalation of radon emanating from household water.

[d] The hazard index is an indicator for potential adverse health effects other than cancer; a hazard index of greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

analysis. If any exposure occurred, the radiation dose could be eliminated by adding new cover materials to the top of the waste area.

I.4.1.1.1 Disposal as U_3O_8

Radiological impacts are presented in Table I.31 for a scenario in which an individual uses contaminated groundwater. In a dry setting, it would take more than 10,000 years for uranium and its decay products to reach the groundwater because of the low water infiltration rate. Therefore, no radiation exposure would occur before 1,000 years in a dry environment, the time frame considered in this analysis.

In a wet setting, the required time for uranium and decay products to reach the groundwater table could be less than 1,000 years after the failure of the disposal facility. The groundwater concentrations would vary from site to site, depending on the specific soil properties (which determine whether the uranium and decay products travel rapidly or slowly in soil). As a result, at 1,000 years after failure of the disposal facility, the radiation dose from using groundwater could range from 41 to 72 mrem/yr for disposal in shallow earthen structures, 48 to 84 mrem/yr for disposal in vaults, and 0.72 to 110 mrem/yr for disposal in a mine. With no remediation effort, the radiation dose could exceed the dose limit of 25 mrem/yr set for low-level waste disposal (10 CFR Part 61). Variation of radiation doses among different disposal types is related to the size of the disposal facility. More discussions are provided in Section I.4.2 regarding the effect of facility dimensions on groundwater concentrations.

I.4.1.1.2 Disposal as UO_2

Variations in disposal settings and disposal types have the same effects on the groundwater concentrations for UO_2 disposal as they do on the groundwater concentrations for U_3O_8 disposal. The time required for uranium and decay products to reach the groundwater table would be greater than 10,000 years for a dry setting, so no impacts would be expected within 1,000 years. The radiation doses estimated for a wet setting for disposal of UO_2 tend to be smaller than those for disposal of U_3O_8 because the waste volume of UO_2 would be less than the volume of U_3O_8 and would require a smaller disposal facility. The doses estimated for use of groundwater range from 34 to 54 mrem/yr for disposal in shallow earthen structures, 34 to 56 mrem/yr for disposal in vaults, and 0.59 to 84 mrem/yr for disposal in a mine at 1,000 years after failure of the disposal facility. With no remediation effort, the exposure could exceed the dose limit of 25 mrem/yr set for low-level waste disposal.

I.4.1.2 Chemical Impacts

Chemical impacts during the post-closure phase are assessed for a hypothetical individual who lives at the border of the disposal site after the institutional control period is over. As for the radiological assessment, potential chemical impacts to human health were evaluated for a scenario involving a hypothetical individual who drills a well at the edge of the disposal site and uses the well water for drinking, irrigating plant foods and fodder, and watering livestock. Leaching of uranium from the disposal area to the groundwater table could potentially result in the hypothetical resident being exposed to uranium from ingestion of drinking water, plant foods, meat, and milk. Risks are estimated on the basis of calculated hazard indices. Information on the exposure assumptions, health effects assumptions, reference doses used for uranium compounds, and calculational methods used in the chemical impact analysis are provided in Appendix C and Cheng et al. (1997).

I.4.1.2.1 Disposal as U_3O_8

Potential health impacts to the general public MEI from exposures to hazardous chemicals due to use of groundwater are presented in Table I.31. Two disposal options are evaluated: disposal as grouted U_3O_8 and ungrouted U_3O_8. The hazard indices for chemical impacts in a dry environment are always zero because the time required for the uranium to reach the groundwater would be greater than 10,000 years due to the low water infiltration rate. In a wet environmental setting, the time to reach groundwater would be less than 1,000 years, but would be dependent on the soil properties (i.e., retardation factor). A retardation factor of 5 results in the uranium reaching the groundwater more quickly and consequently producing greater chemical exposures at 1,000 years than would occur with a retardation factor of 50.

The range of hazard indices for all types of disposal facilities in a wet setting is about 0.1 to 14, exceeding the threshold of 1 for potential adverse health effects. The highest values are for mines, which would require the largest disposal area; and the lowest values are for shallow earthen structures, which would require the smallest disposal area. On the basis of maximum hazard indices, potential chemical impacts are greater for disposal as grouted waste than as ungrouted waste because of the larger waste volume that would be required. Among the groundwater-related exposure pathways that were analyzed, ingestion of drinking water is responsible for more than 80% of the total uranium exposure.

I.4.1.2.2 Disposal as UO_2

Potential human health impacts to the general public MEI from exposures to hazardous chemicals due to groundwater use are presented in Table I.31. Two disposal options were evaluated: disposal as grouted UO_2 and ungrouted UO_2. Differences in environmental settings and types of disposal facilities result in the same variations in groundwater concentrations for UO_2 disposal as they do in the groundwater concentrations for U_3O_8 disposal. Because the waste volume of UO_2

would be less than the volume of U_3O_8, the estimated maximum chemical exposures for UO_2 disposal are consistently less than those for U_3O_8 disposal.

The range of hazard indices for all types of UO_2 disposal facilities in a wet setting is about 0.1 to 10, exceeding the threshold of 1 for potential adverse health effects. The highest values are for mines, which would require the largest disposal area; and the lowest values are for shallow earthen structures, which would require the smallest disposal area. Based on maximum hazard indices, potential chemical impacts are greater for disposal as grouted waste because of the larger waste volume that would be required compared with disposal as ungrouted waste.

I.4.2 Groundwater

Potential impacts to groundwater for the three disposal options during the post-closure phase only include changes in groundwater quality. There would be no impacts to effective recharge, depth to groundwater, or the direction of groundwater flow.

I.4.2.1 Shallow Earthen Structure

During the post-closure period, the only potential impacts to groundwater would be to water quality. With time, the roof material would and allow water to infiltrate the disposal facility. This water could corrode the drums and permit leaching of their contents. Although both forms of the disposed material (U_3O_8 and UO_2) are essentially insoluble in water (LLNL 1997), a conservative estimate of dissolution was obtained by assuming that schoepite ($UO_3{\cdot}H_2O$) would form under the aerobic conditions present in the structure.

With additional time (several hundred to thousands of years), the facility would fail completely, and dissolved schoepite would infiltrate the soil beneath the structure and interact with soil water present in the unsaturated zone. For the shallow earthen structure, this soil water would have a nearly neutral pH (about 7). For the ungrouted case, this interaction would have no impact, and the dissolved schoepite would move vertically downward toward the water table. Transport of the schoepite would be influenced by advection, dispersion, adsorption, and decay (Tomasko 1997).

For the grouted wastes, schoepite was again assumed to form at a concentration equal to its equilibrium value, although carbonates might also form, depending on the type of grout used and site-specific conditions. Because schoepite is about two million times more soluble under the high pH conditions that would occur for the grouted forms of the waste (pH between 10 and 12), the disposed material would dissolve at greatly different rates. However, once the schoepite reached the groundwater, its concentration would be oversaturated relative to the soil water, and it would precipitate and then slowly redissolve. After redissolving, it would be transported vertically downward through the unsaturated zone in the same way that transport would occur for the ungrouted case (Tomasko 1997).

At the water table, schoepite would mix with initially clean water in the uppermost groundwater aquifer and be diluted. After mixing and dilution, the contaminants would be transported in a direction consistent with natural flow. Advection, dispersion, adsorption, and decay would again influence the transport process (Tomasko 1997).

Uranium concentrations and activities at the water table for a wet environmental setting are summarized in Table I.32 for 1,000 years after failure. Values are shown for lateral distances of 0 and 1,000 ft (300 m) downgradient of the facility. For a dry setting, the concentrations would be very small (nearly zero) and are not shown. Additional details on the calculations for the dry location are presented in Tomasko (1997).

The highest uranium groundwater concentrations (270 pCi/L; 1,100 μg/L) would result from a grouted U_3O_8 wasteform; the lowest concentrations (188 pCi/L; 760 μg/L) would result from ungrouted UO_2 (see Table I.32). All of the predicted concentrations would exceed the U.S. Environmental Protection Agency (EPA) proposed maximum contaminant level (MCL) of 20 μg/L (EPA 1996) used for comparison. In all cases, concentrations from grouted wasteforms would be higher than those from ungrouted forms over the long term. This result occurs because a larger facility would be required for the grouted wastes, which would, in turn, reduce the amount of subsequent dilution when the leachate mixes with water in the underlying aquifer. Impacts to groundwater quality could be reduced by decreasing the size of the facility in a direction parallel to the direction of groundwater flow, thereby increasing dilution. The relative concentrations for the decay products formed during transport are reported in Tomasko (1997).

Varying the distance to the receptor from 0 to 1,000 ft (300 m) would have no effect on concentrations if the uranium was relatively mobile in the soil (a retardation of 5 [Table I.32]). This result occurs because of hydrological conditions present in the soil beneath the facility in the wet environment (Tomasko 1997). If the uranium was less mobile and had a retardation coefficient of 50, the concentration at 1,000 years at a lateral distance of 1,000 ft (300 m) would be about 100 times less than the concentration directly below the edge of the facility (0 ft) (Table I.32).

I.4.2.2 Vault

The disposal vault would be located in a dry or wet environment. Because of the design of the facility with a concrete slab roof and other engineered barriers (LLNL 1997), the vault would be expected to have an effective life ranging from several hundred years to tens of thousands of years. Failure of this facility would parallel the failure process described for the shallow earthen structure, and the only impacts to groundwater would be changes in quality once the facility failed completely.

Uranium concentrations in groundwater at 1,000 years for distances of 0 and 1,000 ft (300 m) from the edge of the vault are given in Table I.32. As for the shallow earthen structure, concentrations in the dry environment would be nearly zero, and are not presented here. At 1,000 years, uranium concentrations for a relatively mobile uranium species (retardation coefficient

TABLE I.32 Uranium Activity and Schoepite Concentration in Groundwater for the Disposal Options at 1,000 Years in a Wet Environmental Setting: Retardation Factor = 5 or 50[a]

	Uranium Activity (pCi/L) at Two Distances from Edge of Disposal Facility			
	X = 0 ft		X = 1,000 ft	
Option/Uranium Oxide	Rf = 5	Rf = 50	Rf = 5	Rf = 50
Shallow earthen structure				
Grouted U_3O_8	270	184	270	2.4
Ungrouted U_3O_8	226	154	226	2.0
Grouted UO_2	204	139	204	1.8
Ungrouted UO_2	188	128	188	1.7
Vault				
Grouted U_3O_8	315	214	315	2.8
Ungrouted U_3O_8	264	180	264	2.4
Grouted UO_2	209	142	209	1.9
Ungrouted UO_2	189	129	189	1.7
Mine				
Grouted U_3O_8	425	3.3	425	0
Ungrouted U_3O_8	350	2.7	350	0
Grouted UO_2	316	2.4	316	0
Ungrouted UO_2	289	2.2	289	0

	Schoepite ($UO_3 \cdot 2H_2O$) Concentration (μg/L) at Two Distances from Edge of Disposal Facility			
	X = 0 ft		X = 1,000 ft	
Option/Uranium Oxide	Rf = 5	Rf = 50	Rf = 5	Rf = 50
Shallow earthen structure				
Grouted U_3O_8	1,100	740	1,100	9.7
Ungrouted U_3O_8	910	620	910	8.1
Grouted UO_2	820	560	820	7.3
Ungrouted UO_2	760	520	760	6.9
Vault				
Grouted U_3O_8	1,300	860	1,300	11
Ungrouted U_3O_8	1,100	730	1,100	9.7
Grouted UO_2	840	570	840	7.7
Ungrouted UO_2	760	520	760	6.9
Mine				
Grouted U_3O_8	1,700	13	1,700	0
Ungrouted U_3O_8	1,400	11	1,400	0
Grouted UO_2	1,300	9.7	1,300	0
Ungrouted UO_2	1,200	8.9	1,200	0

[a] The retardation factor (Rf) describes how readily a contaminant such as uranium moves through the soil to the groundwater. An Rf of 5 represents a case in which the uranium moves relatively rapidly through the soil, whereas an Rf of 50 represents a case in which the uranium moves very slowly through the soil.

of 5) would be the same at 0 and 1,000 ft (300 m) downstream of the facility because of the hydrological characteristics of the saturated zone (Tomasko 1997). The maximum concentration of uranium would be 315 pCi/L (1,300 µg/L) for grouted U_3O_8, and the minimum concentration (189 pCi/L; 760 µg/L) would occur for ungrouted UO_2 (Table I.32). These values would exceed the proposed EPA MCL of 20 µg/L (EPA 1996) used for comparison. The differences in concentrations between the different wasteforms primarily results from differences in the size of the facility. That is, the larger the facility, the greater the concentration because of decreased dilution. Impacts to groundwater quality could be reduced by decreasing the size of the facility in a direction parallel to the direction of groundwater flow, thereby increasing dilution (Tomasko 1997).

If the uranium were less mobile in the saturated zone and had a retardation coefficient of 50, uranium concentrations at 1,000 ft (300 m) would be about 100 times less than the concentration directly below the edge of the facility. Because of design considerations (size of the facility), the concentrations from the vault would be greater than those from the shallow earthen structure by about a factor of 1.2 (Tomasko 1997).

I.4.2.3 Mine

For disposal in a mine, waste would be placed in a mine hundreds of feet below the ground surface to minimize intrusion and potential erosion of a surface cap. The effective life of the mine would be expected to be thousands of years. As with the shallow earthen structure and vault, the only impacts to groundwater would be to quality once the facility failed completely.

If the disposal site were located in a dry environment, all of the resulting uranium concentrations at 1,000 years would be nearly zero (Tomasko 1997). In a wet climate, the uranium concentrations would all greatly exceed the proposed EPA MCL if the uranium was mobile (retardation coefficient of 5) (Table I.32) because the distance from the bottom of the mine to the top of the next lower aquifer was assumed to be small (100 ft). If the schoepite was less mobile (retardation coefficient of 50), uranium concentrations in groundwater after 1,000 years would be much less than the EPA proposed MCL and would be the smallest of all the disposal options considered (Table I.32) because the mine was assumed to be located at a distance of 100 ft (30 m) from the water table, whereas the shallow earthen structure and vault were assumed to be 30 ft (9.1 m) from the underlying aquifer. Impacts to groundwater quality could be reduced by decreasing the size of the facility in a direction parallel to the direction of groundwater flow, thereby increasing dilution (Tomasko 1997).

I.4.3 Ecology

Predicted concentrations of contaminants in groundwater were compared to benchmark values of toxic and radiological effects to assess impacts to biota. Discussion of assessment methodology is presented in Appendix C.

I.4.3.1 Disposal as U_3O_8

The disposal facilities considered would be expected to adequately prevent the release of their contents for considerable periods of time. Impacts to ecological resources due to the presence of the facility would not be expected to occur prior to facility failure. Failure of facility integrity would result in contamination of groundwater if the facility was located in a wet environmental setting (typical of the eastern United States, with at least 40 in./yr [100 cm/yr] precipitation). Groundwater could discharge to the surface (such as in wetland areas) near the facility, thus exposing biota to contaminants. Groundwater concentrations of schoepite ($UO_3{\cdot}2H_2O$) were calculated for 1,000 years after facility failure (Section I.4.2). Schoepite concentrations would be nearly zero throughout the time period analyzed for a disposal facility located in a dry environmental setting (typical of the western United States, with less than 10 in./yr [25 cm/yr] precipitation). Ecological impacts are summarized in Table I.33.

Failure of a shallow earthen structure disposal facility would result in groundwater concentrations of schoepite near the facility ranging from 3.1×10^{-6} to 1.1×10^{-3} g/L (0.003 to 1.5 ppm). Soluble uranium compounds can produce toxic effects in aquatic biota at concentrations as low as 1.5×10^{-4} g/L (0.15 ppm). An organism continuously exposed to the undiluted groundwater could therefore be adversely impacted by the toxic effects of uranium. Uranium activity would range from 2.0 to 270 pCi/L (Section I.4.2). Resulting dose rates to maximally exposed organisms would be less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d for aquatic organisms specified in DOE Order 5400.5.

Failure of a facility for disposal in vaults would result in groundwater concentrations of schoepite ranging from 9.7×10^{-6} to 1.3×10^{-3} g/L (0.01 to 1.3 ppm). Therefore an organism continuously exposed to this undiluted groundwater could be adversely impacted by the toxic effects of uranium. Uranium activity would range from 2.4 to 315 pCi/L (Section I.4.2). Resulting dose rates to maximally exposed organisms would be less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

Failure of a mine disposal facility would result in groundwater concentrations ranging from 0 to 1.7×10^{-3} g/L (1.7 ppm). Adverse impacts to aquatic biota could result from exposure to soluble uranium compounds within this concentration range. Uranium activity would range from 0 to 425 pCi/L (Section I.4.2). Resulting dose rates to maximally exposed organisms would be less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

I.4.3.2 Disposal as UO_2

Groundwater schoepite concentrations resulting from the failure of a facility for disposal of UO_2 would also be nearly zero at 1,000 years for a facility in a dry environmental setting. Groundwater concentrations for disposal of UO_2 in a wet environmental setting would be similar to those for disposal of U_3O_8.

TABLE I.33 Potential Radiological and Chemical Impacts to Aquatic Biota due to Failure of a Disposal Facility

Option/Contaminant	Maximum Exposure	Effect
Disposal as U_3O_8		
Shallow earthen structure		
Uranium in groundwater	2.0 to 270 pCi/L	Negligible
Uranium in groundwater	3.1×10^{-6} to 1.1×10^{-3} g/L	Moderate
Vault		
Uranium in groundwater	2.4 to 315 pCi/L	Negligible
Uranium in groundwater	9.7×10^{-6} to 1.3×10^{-3} g/L	Moderate
Mine		
Uranium in groundwater	0 to 425 pCi/L	Negligible
Uranium in groundwater	0 to 1.7×10^{-3} g/L	Negligible to moderate
Disposal as UO_2		
Shallow earthen structure		
Uranium in groundwater	1.7 to 204 pCi/L	Negligible
Uranium in groundwater	6.9×10^{-6} to 8.2×10^{-4} g/L	Moderate
Vault		
Uranium in groundwater	1.7 to 209 pCi/L	Negligible
Uranium in groundwater	6.9×10^{-6} to 8.4×10^{-4} g/L	Moderate
Mine		
Uranium in groundwater	0 to 316 pCi/L	Negligible
Uranium in groundwater	0 to 1.3×10^{-3} g/L	Negligible to moderate

Failure of a shallow earthen structure facility would result in groundwater concentrations of schoepite near the facility ranging from 6.9×10^{-6} to 8.2×10^{-4} g/L (0.007 to 0.82 ppm). Soluble uranium compounds can produce toxic effects in aquatic biota at concentrations as low as 1.5×10^{-4} g/L (0.15 ppm). An organism continuously exposed to the undiluted groundwater could be adversely impacted by the toxic effects of uranium. Uranium activity would range from 1.7 to 204 pCi/L (Section I.4.2). Resulting dose rates to maximally exposed organisms would be less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

Failure of a facility for disposal in vaults would result in groundwater concentrations of schoepite ranging from 6.9×10^{-6} to 8.4×10^{-4} g/L (0.007 to 0.84 ppm). Therefore, an organism continuously exposed to this undiluted groundwater could be adversely impacted by the toxic effects of uranium. Uranium activity would range from 1.7 to 209 pCi/L (Section I.4.2). Resulting dose rates to maximally exposed organisms would be less than 0.015 rad/d, less than 2% of the dose limit of 1 rad/d.

Failure of a mined cavity disposal facility would result in groundwater schoepite concentrations ranging from 0 to 1.3×10^{-3} g/L (1.3 ppm). Adverse impacts to aquatic biota could result from exposure to soluble uranium compounds within this concentration range. Uranium activity would range from 0 to 316 pCi/L (Section I.4.2). Resulting dose rates to maximally exposed organisms would be considerably lower than the dose limit of 1 rad/d.

I.5 REFERENCES FOR APPENDIX I

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Cheng, J.-J., et al., 1997, *Human Health Impact Analyses for Normal Operations in Support of the Depleted Uranium Hexafluoride Programmatic Environmental Impact Statement*, attachment to memorandum from J.-J. Cheng (Argonne National Laboratory, Argonne, Ill.) to H.I. Avci (Argonne National Laboratory, Argonne, Ill.), May 21.

DOE: see U.S. Department of Energy.

EPA: see U.S. Environmental Protection Agency.

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APPENDIX J:

ENVIRONMENTAL IMPACTS OF TRANSPORTATION OF UF_6 CYLINDERS, URANIUM OXIDE, URANIUM METAL, AND ASSOCIATED MATERIALS

CONTENTS (APPENDIX J)

TABLES

TABLES (Cont.)

TABLES (Cont.)

NOTATION (APPENDIX J)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
ICRP	International Commission on Radiological Protection
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
PEIS	programmatic environmental impact statement

Chemicals

CaF_2	calcium fluoride
HF	hydrogen fluoride; hydrofluoric acid
MgF_2	magnesium fluoride
NH_3	ammonia
UF_6	uranium hexafluoride
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

ft	foot (feet)
h	hour(s)
kg	kilogram(s)
km	kilometer(s)
lb	pound(s)
m	meter(s)
mrem	millirem(s)

APPENDIX J:

ENVIRONMENTAL IMPACTS OF TRANSPORTATION OF UF_6 CYLINDERS, URANIUM OXIDE, URANIUM METAL, AND ASSOCIATED MATERIALS

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites in Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period from 1999 through 2039. This appendix provides detailed information describing the transportation of radioactive and other hazardous materials associated with the options considered in the PEIS. The discussion provides background information, as well as a summary of the estimated environmental impacts associated with transportation.

> **Transportation**
>
> The transportation of hazardous and radioactive materials was assessed for all alternative strategies considered in the PEIS for management of the depleted UF_6 inventory currently stored at three DOE sites. For purposes of analysis, it was assumed that all long-term storage, conversion, disposal, and manufacture and use facilities would be located at different sites, thus requiring the transportation of materials between sites. The PEIS transportation assessment considered the impacts from all shipments associated with each category of the options that make up the alternatives. The materials considered include depleted UF_6 cylinders, uranium conversion products, chemicals required for or produced during processing (such as hydrogen fluoride and hydrochloric acid), as well as any low-level radioactive, low-level mixed radioactive, and hazardous waste generated during operations. The analysis considered both truck and rail shipment options.

All of the PEIS alternatives would involve some transportation of radioactive and hazardous materials. For purposes of the PEIS analysis, it was assumed that all long-term storage, conversion, disposal, and manufacture and use facilities would be located at different locations. Thus, transportation would form the links between the options that make up each of the PEIS alternatives, as shown graphically in Chapter 2, Figures 2.2 through 2.6. In reality, the transportation activities actually required by an alternative would depend on the locations of the facilities involved — if facilities were colocated, the transportation of materials, and any associated impacts, would be minimized or eliminated.

The transportation assessment considered all shipments associated with the categories of options that make up each of the PEIS alternatives. The primary uranium materials transported under these alternatives include depleted UF_6 cylinders, uranium oxide (uranium dioxide [UO_2] or triuranium octaoxide [U_3O_8]), uranium metal, and uranium oxide and uranium metal storage casks (see Table J.1). Also, each alternative would involve transportation of chemicals required for or

TABLE J.1 Primary Uranium Materials Transported under Each Management Alternative

	Primary Material Transported[a]				
PEIS Alternative	Depleted UF_6 Cylinders	Oxide (UO_2 or U_3O_8)	Uranium Metal	Uranium Oxide Casks	Uranium Metal Casks
No action	–	–	–	–	–
Long-term storage as UF_6	X[b]	–	–	–	–
Long-term storage as oxide	X	X	–	–	–
Use as uranium oxide	X	X	–	X	–
Use as uranium metal	X	–	X	–	X
Disposal	X	X	–	–	–

[a] In addition to the uranium materials listed, each alternative would also involve the transportation of chemicals required for or produced during processing, as well as LLW and LLMW.

[b] X indicates that the material was assumed to be transported under that PEIS alternative.

produced during processing (such as hydrogen fluoride [HF]), as well as any low-level radioactive waste (LLW), low-level mixed waste (LLMW), and hazardous chemical waste generated during operations.

Impacts from the on-site transportation of the various materials at the different facilities (conversion, storage, manufacture, and disposal) were not computed. On-site transportation impacts are expected to be negligible when compared with the impacts associated with the off-site transportation between facilities. On-site shipments of over 19 miles (30 km) were assessed for the Hanford site for comparison with off-site shipments analyzed in the *Waste Management Programmatic Environmental Impact Statement* (DOE 1997). The on-site impacts were found to be more than 100 times smaller than the off-site impacts, primarily because of the much shorter shipment distances involved (Biwer et al. 1996). For the depleted UF_6 PEIS, shorter on-site distances are likely; therefore, the on-site transportation impacts are also expected to be more than 100 times smaller than the off-site impacts. The decisions to be made based on this PEIS would not be affected by on-site transportation impacts. In addition, transportation impacts would be much smaller for on-site shipments than off-site shipments and would also be smaller than the impacts associated with loading and unloading shipments for off-site shipments, which were included in the involved worker doses estimated for facility operations.

Additional details regarding the methodology used to assess transportation impacts are provided in Biwer et al. (1997).

J.1 SUMMARY OF TRANSPORTATION OPTION IMPACTS

The potential environmental impacts associated with transportation activities for the PEIS alternatives are summarized in Table J.2. For purposes of comparison in Table J.2, the analysis was based on the assumption that all shipments would be transported a distance of 620 miles (1,000 km), regardless of the type of material. (Transportation impacts were evaluated for distances ranging from 155 to 3,100 mi [250 to 5,000 km] in Section J.3.) The assessment considered impacts on human health that would result from the radioactive and hazardous chemical characteristics of the materials shipped, as well as the impacts that would result from operation of the transportation vehicles. Additional discussion and details related to the results for individual areas of impact are provided in Section J.3.

Various options were considered for each alternative, including the following transportation-related steps:

- ***No Action Alternative.*** No off-site transportation is expected under the no action alternative, except for a few LLW and LLMW shipments. Minor amounts of LLW and LLMW may be generated during monitoring and maintenance activities associated with the storage of the depleted UF_6 cylinders at their current locations. Fewer than one shipment per year to a disposal site would be expected for the waste generated, and no fatalities would be anticipated from waste shipments. Shipment impacts are expected to be negligible, similar to LLW and LLMW shipments from the cylinder treatment facility or the cylinder transfer facility as considered under other alternatives.

- ***Long-Term Storage as UF_6.*** Long-term storage as UF_6 would involve transportation of the depleted UF_6 cylinders from the three existing storage sites to a long-term storage facility. The cylinders might be shipped in overcontainers. If a transfer facility were used to alleviate the problem of substandard cylinders before shipment of the UF_6, shipment of LLW and LLMW from the transfer facility would be required.

- ***Long-Term Storage as Oxide.*** Long-term storage as oxide (UO_2 or U_3O_8) would involve transportation of the depleted UF_6 cylinders to an oxide conversion plant. The conversion facility would also require inbound shipments of ammonia and outbound shipments of HF and waste. Cleaning of the empty cylinders at a cylinder treatment facility colocated with the conversion facility would require outbound shipments of U_3O_8 and waste. The final transportation step would be shipment of the oxide to the long-term storage facility.

TABLE J.2 Summary of Transportation Impacts by Alternative[a]

Impacts from Long-Term Storage as UF_6	Impacts from Long-Term Storage as Oxide	Impacts from Use as Uranium Oxide Cask	Impacts from Use as Uranium Metal Cask	Impacts from Disposal
Total Shipments: LLW (cylinder transfer): 460 – 580 LLMW (cylinder transfer): 60 Cylinders: 11,606 – 46,666	**Total Shipments:** LLW (cylinder transfer): 460 – 580 LLMW (cylinder transfer): 60 Cylinders: 11,606 – 46,666 HF: 0 – 4,860 NH_3: 0 – 1,120 LLW (oxide conversion): 320 – 1,680 LLMW (oxide conversion): 20 – 40 CaF_2: 180 – 19,760 Oxide: 8,480 – 26,800	**Total Shipments:** LLW (cylinder transfer): 460 – 580 LLMW (cylinder transfer): 60 Cylinders: 11,606 – 46,666 HF: 0 – 4,860 NH_3: 0 – 1,120 LLW (UO_2 conversion): 360 – 1,680 LLMW (UO_2 conversion): 20 – 40 CaF_2: 180 – 19,760 Oxide: 8,480 – 26,800 LLW (cask manufacture): 300 LLMW (cask manufacture): 20 Uranium oxide casks: 9,600	**Total Shipments:** LLW (cylinder transfer): 460 – 580 LLMW (cylinder transfer): 60 Cylinders: 11,606 – 46,666 HF: 1,640 NH_3: 920 LLW (metal conversion): 360 – 3,840 LLMW (metal conversion): 20 MgF_2: 3,800 – 10,780 Metal: 7,360 – 21,500 LLW (cask manufacture): 1,540 LLMW (cask manufacture): 20 Uranium metal casks: 9,060	**Total Shipments:** LLW (cylinder transfer): 460 – 580 LLMW (cylinder transfer): 60 Cylinders: 11,606 – 46,666 HF: 0 – 4,860 NH_3: 0 – 1,120 LLW (oxide conversion): 320 – 1,680 LLMW (oxide conversion): 20 – 40 CaF_2: 180 – 19,760 Oxide: 8,480 – 26,800
		Human Health – Normal Operations: Radiological[b]		
Workers and Public: Total number of LCFs: 0.1 Maximum risk of LCF to MEI member of general public (resident along route): $9 \times 10^{-15} - 8 \times 10^{-12}$	**Workers and Public:** Total number of LCFs: 0.1 – 0.3 Maximum risk of LCF to MEI member of general public (resident along route): $9 \times 10^{-15} - 8 \times 10^{-12}$	**Workers and Public:** Total number of LCFs: 0.1 – 0.3 Maximum risk of LCF to MEI member of general public (resident along route): $9 \times 10^{-15} - 8 \times 10^{-12}$	**Workers and Public:** Total number of LCFs: 0.1 – 0.2 Maximum risk of LCF to MEI member of general public (resident along route): $9 \times 10^{-15} - 8 \times 10^{-12}$	**Workers and Public:** Total number of LCFs: 0.1 – 0.3 Maximum risk of LCF to MEI member of general public (resident along route): $9 \times 10^{-15} - 8 \times 10^{-12}$
		Human Health – Normal Operations: Chemical		
Workers and Public: Fatalities from vehicle exhaust emissions: 0.04 – 0.2	**Workers and Public:** Fatalities from vehicle exhaust emissions: 0.08 – 0.4	**Workers and Public:** Fatalities from vehicle exhaust emissions: 0.1 – 0.5	**Workers and Public:** Fatalities from vehicle exhaust emissions: 0.08 – 0.4	**Workers and Public:** Fatalities from vehicle exhaust emissions: 0.08 – 0.4

TABLE J.2 (Cont.)

Impacts from Long-Term Storage as UF_6	Impacts from Long-Term Storage as Oxide	Impacts from Use as Uranium Oxide Cask	Impacts from Use as Uranium Metal Cask	Impacts from Disposal
		Human Health – Accidents: Radiological[b]		
Overall accident risk (LCFs): 0.00007 – 0.0005	Overall accident risk (LCFs): 0.001 – 0.007	Overall accident risk (LCFs): 0.001 – 0.007	Overall accident risk (LCFs): 0.00007 – 0.0005	Overall accident risk (LCFs): 0.001 – 0.007
Bounding accident: UF_6 cylinder rail accident in urban area	Bounding accident: UF_6 cylinder rail accident in urban area	Bounding accident: UF_6 cylinder rail accident in urban area	Bounding accident: UF_6 cylinder rail accident in urban area	Bounding accident: UF_6 cylinder rail accident in urban area
Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km
Bounding accident consequences to population within 50 miles (per occurrence): 60 LCFs	Bounding accident consequences to population within 50 miles (per occurrence): 60 LCFs	Bounding accident consequences to population within 50 miles (per occurrence): 60 LCFs	Bounding accident consequences to population within 50 miles (per occurrence): 60 LCFs	Bounding accident consequences to population within 50 miles (per occurrence): 60 LCFs
Bounding accident consequences to MEI (per occurrence): Risk of LCF: 0.002	Bounding accident consequences to MEI (per occurrence): Risk of LCF: 0.002	Bounding accident consequences to MEI (per occurrence): Risk of LCF: 0.002	Bounding accident consequences to MEI (per occurrence): Risk of LCF: 0.002	Bounding accident consequences to MEI (per occurrence): Risk of LCF: 0.002

TABLE J.2 (Cont.)

Impacts from Long-Term Storage as UF_6	Impacts from Long-Term Storage as Oxide	Impacts from Use as Uranium Oxide Cask	Impacts from Use as Uranium Metal Cask	Impacts from Disposal
		Human Health – Accidents: Chemical		
Overall accident risk (irreversible adverse effects): 1×10^{-6} – 0.00003	Overall accident risk (irreversible adverse effects): 0.5 – 20	Overall accident risk (irreversible adverse effects): 0.5 – 20	Overall accident risk (irreversible adverse effects): 7	Overall accident risk (irreversible adverse effects): 0.5 – 20
Bounding accident: UF_6 cylinder rail accident in urban area	Bounding accident: HF rail accident in urban area	Bounding accident: HF rail accident in urban area	Bounding accident: HF rail accident in urban area	Bounding accident: HF rail accident in urban area
Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-9} per railcar-km	Bounding accident frequency: 1×10^{-90} per railcar-km
Bounding accident consequences to population within 50 miles (per occurrence): up to 4 irreversible adverse effects	Bounding accident consequences to population within 50 miles (per occurrence): up to 30,000 irreversible adverse effects	Bounding accident consequences to population within 50 miles (per occurrence): up to 30,000 irreversible adverse effects	Bounding accident consequences to population within 50 miles (per occurrence): up to 30,000 irreversible adverse effects	Bounding accident consequences to population within 50 miles (per occurrence): up to 30,000 irreversible adverse effects
Bounding accident consequences to MEI (per occurrence): expected irreversible adverse effects	Bounding accident consequences to MEI (per occurrence): expected irreversible adverse effects	Bounding accident consequences to MEI (per occurrence): expected irreversible adverse effects	Bounding accident consequences to MEI (per occurrence): expected irreversible adverse effects	Bounding accident consequences to MEI (per occurrence): expected irreversible adverse effects
		Human Health — Accidents: Physical Hazards		
Total traffic fatalities: 0.6 – 2	Total traffic fatalities: 1 – 4	Total traffic fatalities: 2 – 4	Total traffic fatalities: 1 – 3	Total traffic fatalities: 1 – 4

[a] Shipping distance of 621 miles (1,000 km) for all materials; vehicle-related impacts were based on round-trip distance. The no action alternative is not included in this table (see Table J.1). Fewer than one off-site shipment per year to a disposal site would be expected for the minor amounts of LLW and LLMW generated during monitoring and maintenance activities under this alternative.

[b] Radiological LCFs were estimated from the calculated dose using dose-to-risk conversion factors of 0.0005 and 0.0004 fatalities per person-rem for members of the general public and occupational workers, respectively, as recommended in Publication 60 of the International Commission on Radiological Protection (ICRP 1991). The approximate corresponding dose for each of the radiological fatality risks listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

Notation: CaF_2 = calcium fluoride; HF = hydrogen fluoride; LCF = latent cancer fatality; LLW = low-level radioactive waste; LLMW = low-level mixed waste; MEI = maximally exposed individual; MgF_2 = magnesium fluoride; NH_3 = ammonia; UF_6 = uranium hexafluoride; UO_2 = uranium dioxide.

- ***Use as Uranium Oxide Casks.*** Use as uranium oxide casks would involve transportation of the depleted UF_6 cylinders to a UO_2 conversion plant. The conversion facility would also require inbound shipments of ammonia and outbound shipments of HF and waste. Cleaning of the empty cylinders at a cylinder treatment facility colocated with the conversion facility would require outbound shipments of U_3O_8 and waste. The UO_2 would be transported to a cask manufacturing facility, which would also generate some waste for shipment to disposal. Finally, the casks would be shipped to an end user.

- ***Use as Uranium Metal Casks.*** Use as uranium metal casks would involve transportation of the depleted UF_6 cylinders to a metal conversion plant. The conversion facility would also require inbound shipments of ammonia and outbound shipments of HF and waste. Cleaning of the empty cylinders at a cylinder treatment facility colocated with the conversion facility would require outbound shipments of U_3O_8 and waste. The metal would be transported to a cask manufacturing facility, which would also generate some waste for shipment to disposal. Finally, the casks would be shipped to an end user.

- ***Disposal.*** The disposal option would involve the same transportation steps required for long-term storage as oxide, except that the final shipments of oxide would be sent to a disposal facility rather than a storage facility.

The transportation impacts in Table J.2 are presented as ranges of values. The ranges reflect differences in risk between truck and rail modes and differences in the types and quantities of materials required within a given option. The following is a general summary of potential impacts from transportation activities (based on information in Table J.2 and additional detailed information in Section J.3):

- The analysis of transportation risks presented in Table J.2 was based on the assumption that all shipments would travel a distance of 620 miles (1,000 km) and that essentially the entire inventory of DOE-generated depleted uranium would be shipped between long-term storage, conversion, manufacture and use, and disposal facilities. Transportation risks would be reduced or eliminated by colocating facilities or minimizing shipment distances between facilities.

- In general, the greatest risk from transportation would result from vehicle-related physical hazards, that is, potential fatalities caused by the physical trauma received during transportation accidents, independent of the material transported. This risk would increase directly with the number of shipments and shipment distance.

- The overall transportation risk resulting from the radioactive characteristics of the transported material would be small, generally less than one-tenth of the risk from vehicle-related causes for a given shipment.

- The overall transportation risk resulting from the hazardous chemical characteristics of the transported material would also be small, generally less than one-tenth of the risk from vehicle-related causes for most shipments.

- There is potential for low-probability, severe transportation accidents that could have large consequences. The accidents with the largest potential consequences would be rail accidents involving a tank car containing HF. Under unfavorable weather conditions, the HF released from these accidents could result in approximately 10 irreversible adverse effects in a rural environment or approximately 30,000 irreversible adverse effects in an urban environment. These impacts are discussed in Section J.3.4.2.

- Within each material category, the total transportation risk would be dominated by shipments of depleted UF_6 cylinders, U_3O_8, UO_2, uranium metal, and uranium oxide and uranium metal casks because of the large number of shipments required for these materials. Shipments of waste and process chemicals would not contribute significantly to the overall risk, except for potential shipments of the ammonia required for some conversion options and the HF by-product associated with some conversion options.

- In general, rail transportation would result in a slightly lower overall risk than truck transportation for the same amount of material, due primarily to higher rail shipment capacities and therefore fewer shipments.

J.2 TRANSPORTATION MODES

This assessment of transportation impacts was based on data provided in the engineering analysis report (Lawrence Livermore National Laboratory [LLNL 1997]). For each category of option assessed in the PEIS, the engineering analysis report provides estimates of the types, characteristics, and quantities of each material that would require transportation.

J.2.1 Truck Transportation

Truck transportation was considered for all materials shipped, except for some bulk shipments of HF, ammonia, and spent nuclear fuel casks (which are too large for road transport). Truck shipments would generally be in legal-weight semitrailer trucks, consistent with current practices. The maximum gross vehicle weight for truck shipments is limited by the U.S. Department of

Transportation (DOT) to 80,000 lb (36,400 kg). Truck shipments of depleted UF_6 were assumed to consist of a single cylinder per trailer. Shipments of conversion products and waste materials would generally be near the maximum allowed by weight limitations.

J.2.2 Rail Transportation

Rail transportation was considered as an option to truck transportation for the shipment of bulk materials where the amount of material shipped would justify the use of full railcars. These materials would include depleted UF_6 cylinders and conversion products. For rail transportation, the average payload weights for boxcars range from 100,000 to 150,000 lb (45,000 to 68,000 kg). Rail shipments of depleted UF_6 were assumed to consist of four cylinders per railcar, with transport by regular freight train service. In general, rail transportation was not considered for shipments of waste materials and most chemicals generated or used during processing because the annual volumes of these materials would be much less than typical railcar capacities.

J.2.3 Transportation Options Considered But Not Analyzed in Detail

Air and barge transportation options were considered but not analyzed in detail. Air transportation would be prohibitively expensive and is not practical for shipping waste and large amounts of material. The use of barge transportation for the depleted UF_6 cylinders, conversion products, or manufactured products was considered but not examined in detail because sites for the proposed facilities under consideration in the PEIS have not yet been determined. Generic input parameters to estimate the risks associated with barge transport are not as readily applicable as they are for truck or rail transport because of the fixed and limited nature of the inland and coastal waterways.

The use of barge transport for bulk shipments of depleted uranium materials would be a viable alternative if both the shipping and receiving sites were located near the U.S. inland or coastal waterway systems. In general, the risk per shipment would be approximately the same as for a truck or rail (one railcar) shipment, but fewer shipments would be necessary and the costs per ton-mile much lower. The primary risks to workers would occur during loading and unloading operations. Risks to the public could occur in the vicinity of locks when the barges were stopped during their passage through the locks and from accidents that might result in potential releases to the environment. Barge transport of the depleted UF_6 cylinders from the existing storage sites would first require truck or rail transport to the nearest river port, approximately 20 to 25 miles (32 to 40 km) for the Portsmouth and Paducah sites and approximately 1 mile (1.6 km) for the K-25 site.

J.3 IMPACTS OF OPTIONS

The potential environmental impacts associated with transportation activities are summarized in this section. Additional information related to the assessment methodologies for each area of impact is provided in Appendix C.

J.3.1 General Assumptions

The environmental impacts from transportation were evaluated for each category of option (i.e., cylinder preparation, conversion, long-term storage, manufacture and use, and disposal) on the basis of information described in the engineering analysis report (LLNL 1997). The materials transported for each option category are summarized in Table J.3, along with the origin and destination sites for each material and an indication of whether the material poses a radiological, chemical, or vehicle-related risk. The following general assumptions apply to the assessment of impacts:

- Because sites for long-term storage, conversion, disposal, and manufacture and use will not be selected or known until some time in the future, transportation impacts for each material were estimated as the risk per kilometer traveled, using representative national average route statistics. For comparison, total transportation impacts are presented for shipment distances of 155, 620, and 3,100 miles (250, 1,000, and 5,000 km).

- The assessment of total transportation impacts was based on the assumption that the entire inventory of depleted uranium would be shipped between long-term storage, conversion, manufacture and use, and disposal facilities.

- National average accident occurrence rates (accidents per million miles) and fatality rates (accident fatalities per million miles) were used for accident calculations for truck and rail shipments.

- Transportation impacts were estimated for all shipments of depleted UF_6 cylinders, uranium conversion products, chemicals required for or produced during processing (such as HF and ammonia), as well as any LLW and LLMW generated during operations. Some conversion options would produce large quantities of calcium fluoride (CaF_2) or magnesium fluoride (MgF_2). CaF_2 can be used or disposed of as either sanitary waste or LLW, depending on the residual uranium concentration and applicable regulatory release limits at the time of disposal. Similarly, MgF_2 can be disposed of as sanitary waste or LLW.

TABLE J.3 Summary of Materials Transported for Each Transportation Option

Option Category	Material Transported	Risk			Origin Site	Destination Site
		Radiological	Chemical	Vehicular		
Cylinder preparation	LLW	X	X	X	UF_6 current locations	LLW disposal site
	LLMW	X	X	X	UF_6 current locations	LLMW treatment/disposal site
	Hazardous waste	X	X	X	UF_6 current locations	Hazardous waste disposal site
Conversion	Depleted UF_6	X	X	X	Current locations	Conversion site
	LLW	X	X	X	Conversion site	LLW disposal site
	LLMW	X	X	X	Conversion site	LLMW treatment/disposal site
	Hazardous waste	–	X	X	Conversion site	Hazardous waste disposal site
	U_3O_8	X	X	X	Cylinder treatment facility	Storage or disposal site
	LLW	X	X	X	Cylinder treatment facility	LLW disposal site
	LLMW	X	X	X	Cylinder treatment facility	LLMW treatment/disposal
	Hazardous waste	–	X	X	Cylinder treatment facility	Hazardous waste disposal
	HF and NH_3 (various combinations, depending on conversion option)	–	X	X	Chemical manufacturer or conversion site	Conversion or disposal site
	CaF_2	–	–	X	Conversion site	LLW disposal site
	MgF_2	–	–	X	Conversion site	LLW disposal site
Long-term storage	Depleted UF_6	X	X	X	Current locations	Long-term storage site
	UO_2 or U_3O_8	X	X	X	Conversion site	Long-term storage site
Manufacture and use	Uranium metal or UO_2	X	X	X	Conversion site	Manufacturing site
	LLW	X	X	X	Manufacturing site	LLW disposal site
	LLMW	X	X	X	Manufacturing site	LLMW treatment/disposal site
	Uranium oxide or uranium metal casks	X	–	X	Manufacturing site	End user
Disposal	UO_2 or U_3O_8	X	X	X	Conversion or storage site	Disposal site (shallow earthen structure, vault, or mine)

- For the various options, the transportation risk for a number of shipments listed in the engineering analysis report (LLNL 1997) are not included in this PEIS because they would not pose a radiological risk or a chemical fatality risk. Such shipments include chemicals used for processing (hydrochloric acid, sodium hydroxide, and nitric acid) and output hazardous waste for most facilities. The acids would not be in concentrated form, and sodium hydroxide is not an inhalation hazard. Relatively few drums of hazardous waste would be generated with minor amounts per drum, typically less than 1 or 2 kg of hazardous material, some of which would not be an inhalation hazard.

- In general, transportation activities were assumed to take place over a 20-year period, consistent with the operational period of the facilities considered.

J.3.2 Impacts Considered

The transportation of depleted uranium and associated materials would pose potential risks to human health and the environment. These risks would result from both the radioactive and chemical nature of the materials transported, as well as from operation of the transportation vehicles. The potential risks are discussed in this section. Additional details are given in Appendix C. The collective risks are presented in terms of the expected number of fatalities (or potentially life-threatening effects for chemical impacts) among the general public from all shipments for per-shipment distances ranging from 155 to 3,100 miles (250 to 5,000 km). The risks are presented for both truck and rail options, where appropriate.

J.3.2.1 Human Health — Normal Operations

J.3.2.1.1 Radiological Impacts

Radiological risk associated with routine transportation would result from the potential exposure of people to low levels of external radiation near a radioactive shipment. External exposures could occur as shipments moved past members of the public along routes or while the shipment was stopped along the route. No radioactive materials would be released during routine operations. Collective risks were estimated for the transportation crew members and for members of the public living and working along the transportation routes, sharing the routes, and present at stops along the routes.

In addition to assessing the routine collective population risk, risks to the maximally exposed individual (MEI) were estimated for a number of hypothetical exposure scenarios; these risks are listed in Table J.4. The scenarios include exposure of persons living next to a shipment route or being next to a shipment while stopped in traffic. The scenarios were chosen to provide a

TABLE J.4 Definition of Maximally Exposed Individuals for Assessment of Routine Transportation Risk

Maximally Exposed Individual	Assumptions	Distance (m)	Exposure Duration
Inspector (truck and rail)	Federal or state vehicle inspector, not covered by a dosimetry program	3	30 minutes
Resident (truck and rail)	Person living near a site shipment entrance, not protected by shielding	30	Shipments pass at average speed of 24 km/h
Person at traffic obstruction (truck and rail)	Person stopped next to a radioactive material shipment due to traffic or other causes, not protected by shielding	1	30 minutes
Person at truck service station	Worker at a truck stop	20	2 hours
Resident near a rail stop	Resident living near a rail classification yard, not protected by shielding	200	20 hours

range of exposure conditions; they were not intended to be all inclusive. For the transportation-related radiological impacts assessed in this PEIS, all those resulting from external radiation during routine transport would be very small because the highest level of radiation from any one shipment would be less than 1 mrem/h at a distance of 3.3 ft (1 m) from the transport vehicle. This dose rate is more than 10 times less than the regulatory limit of 10 mrem/h at 6.6 ft (2 m) from the transport vehicle, as directed by the DOT (49 *Code of Federal Regulations* [CFR] Part 173) and the U.S. Nuclear Regulatory Commission (10 CFR Part 71).

J.3.2.1.2 Chemical Impacts

The analysis assumed that no leaks would occur in the shipping packages during normal transport. Therefore, no impacts on human health would be related directly to the hazardous nature of chemical shipments during routine operations.

J.3.2.1.3 Vehicle-Related Impacts (Chemical Hazards)

Vehicle-related health risks are independent of the nature of the cargo and would be incurred for similar shipments of any commodity. The routine risks assessed might be caused by potential exposure to increased levels of airborne particulates from vehicular exhaust emissions and from fugitive dust raised from the roadbed by the transport vehicle. The health endpoint assessed was the excess (additional) latent mortality caused by inhalation of these particulates in urban areas where ambient particulate air concentrations already exceed threshold values thought to be necessary before adverse effects are observed. It was assumed that a latent mortality is equivalent to a latent cancer fatality.

J.3.2.2 Human Health — Accident Conditions

J.3.2.2.1 Radiological Impacts

Radiological impacts from transportation-related accidents could result from the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people through multiple pathways, such as exposure to contaminated soil, inhalation, or ingestion of contaminated food. The radiological impacts are expressed in terms of latent cancer fatalities (LCFs). No acute effects would be expected for the materials relevant to the action under consideration in this PEIS.

The collective accident risks from radiological causes over the life of the project have been estimated for all radioactive material shipments for each option category (see Table J.3 for a list of shipments). The accident risk estimates were based not only on the consequences of potential accidents but also on the probabilities that accidents would occur.

Although the overall radiological accident risk would be small for all shipments, there would be potential for low-probability, severe transportation accidents that could have relatively large consequences. Population and MEI impacts were estimated for such accidents.

J.3.2.2.2 Chemical Impacts

Chemical impacts from transportation-related accidents could result from the potential release and dispersal of hazardous chemicals into the environment during an accident and the subsequent exposure of people through the inhalation pathway. None of the hazardous chemicals involved in the action under consideration are suspected carcinogens, and any acute effects from ingestion or dermal absorption of the contaminants would be expected to be dominated by inhalation effects. The collective accident risks from chemical causes were estimated in the same manner as the radiological risks, taking into account accident probability, the spectrum of accident severities, and accident consequences. The health endpoints presented are potential irreversible adverse effects and expected fatalities, which are discussed in detail in Appendix C and Policastro et al. (1997). Population and MEI consequences from potentially severe accidents are presented.

J.3.2.2.3 Vehicle-Related Impacts (Physical Hazards)

Accident risks from physical hazards are vehicle-related risks that result from the physical trauma created by accidents; such risks are not related to the shipment's cargo. Physical hazard risks represent fatalities from mechanical causes and were determined from fatality rates based on national average statistics maintained by the DOT for truck and rail transportation (Saricks and Kvitek 1994).

J.3.3 Cylinder Preparation Options

Two options were evaluated for preparing nonconforming cylinders for off-site transportation to either a conversion facility or a long-term storage site (see Appendix E). These problem cylinders were classified into three types: (1) overfilled cylinders, (2) overpressurized cylinders, and (3) substandard cylinders. Each of the two cylinder preparation options would prepare all three types of cylinders to meet all DOT requirements for off-site shipment.

J.3.3.1 Cylinder Overcontainers

An overcontainer would be suitable to contain, transport, and store the cylinder contents, regardless of cylinder condition, and could be designed as a pressure vessel enabling liquefaction of the depleted UF_6 for transfer out of the cylinder. Because only minimal cylinder handling operations would be required to load substandard cylinders into an overcontainer, no chemical transportation risks would be associated with this option. Potential risks associated with the transportation of depleted UF_6 cylinders in protective overcontainers are presented in Sections J.3.4.1 and J.3.5.1 for the conversion options and long-term storage options, respectively.

J.3.3.2 Cylinder Transfer Facility

The alternative to placing nonconforming cylinders into overcontainers would be to transfer the depleted UF_6 to new cylinders. A facility necessary to effect such a transfer was assumed to be colocated at each of the three existing sites where the cylinders are currently stored. Therefore, the only transportation risks would be from minor amounts of chemicals used at the facility and small amounts of LLW and LLMW generated at the facility.

The total collective radiological risks (i.e., the total risk to all workers and members of the general public potentially exposed) for shipments associated with the cylinder transfer option are summarized in Tables J.5 and J.6 for routine and accident risks, respectively. Routine risks to MEIs are summarized in Table J.7, whereas potential severe accident consequences to local populations from radiological and chemical hazards are summarized in Tables J.8 and J.9, respectively. Accident consequences to MEIs are summarized in Table J.10.

TABLE J.5 Total Routine Shipment Risks for the Transportation of Materials for the Cylinder Preparation and Conversion Options

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Facility/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF
Cylinder transfer facility											
LLW	Truck	460 – 580	0.00004 – 0.00005	0	0.0005 – 0.0007	0.0001 – 0.0002	0	0.002 – 0.003	0.0007 – 0.0009	0	0.01
LLMW	Truck	20	2×10^{-8}	0	0.00002	1×10^{-7}	0	0.00009	5×10^{-7}	0	0.0005
Depleted UF_6 cylinders[d]											
Paducah	Truck	28,513	0.02	0	0.03	0.08	0	0.1	0.4	0	0.7
	Rail	7,129	0.01	0	0.005	0.02	0	0.02	0.06	0	0.1
Portsmouth	Truck	13,421	0.009	0	0.02	0.04	0	0.06	0.2	0	0.3
	Rail	3,356	0.005	0	0.003	0.008	0	0.01	0.03	0	0.05
Oak Ridge	Truck	4,732	0.003	0	0.006	0.01	0	0.02	0.06	0	0.1
	Rail	1,183	0.002	0	0.0009	0.003	0	0.004	0.01	0	0.02
UF_6 with overcontainers											
Paducah	Truck	28,351	0.01	0	0.03	0.04	0	0.1	0.2	0	0.7
	Rail	7,088	0.009	0	0.005	0.01	0	0.02	0.03	0	0.1
Portsmouth	Truck	13,388	0.005	0	0.02	0.02	0	0.06	0.09	0	0.3
	Rail	3,347	0.004	0	0.003	0.006	0	0.01	0.01	0	0.05
Oak Ridge	Truck	4,683	0.002	0	0.005	0.006	0	0.02	0.03	0	0.1
	Rail	1,171	0.001	0	0.0009	0.002	0	0.004	0.005	0	0.02

TABLE J.5 (Cont.)

Facility/Material	Mode	Total Shipments[a]	Risks over 250 km: Radiological LCF[b]	Risks over 250 km: Chemical Effects[c]	Risks over 250 km: Vehicular LCF	Risks over 1,000 km: Radiological LCF[b]	Risks over 1,000 km: Chemical Effects[c]	Risks over 1,000 km: Vehicular LCF	Risks over 5,000 km: Radiological LCF[b]	Risks over 5,000 km: Chemical Effects[c]	Risks over 5,000 km: Vehicular LCF
U_3O_8 conversion facility											
Ammonia	Truck	0 – 520	NA	0	0 – 0.0006	NA	0	0 – 0.002	NA	0	0 – 0.01
LLW	Truck	320 – 1,420	0.00002 – 0.0001	0	0.0004 – 0.002	0.00009 – 0.0005	0	0.001 – 0.007	0.0005 – 0.003	0	0.007 – 0.03
LLMW	Truck	20	2×10^{-8}	0	0.00002	1×10^{-7}	0	0.00009	5×10^{-7}	0	0.0005
HF	Rail	0 – 4,860	NA	0	0 – 0.004	NA	0	0 – 0.01	NA	0	0 – 0.07
CaF_2	Truck	460 – 19,760	NA	0	0.0005 – 0.02	NA	0	0.002 – 0.09	NA	0	0.01 – 0.5
	Rail	180 – 7,300	NA	0	0.0001 – 0.005	NA	0	0.0005 – 0.02	NA	0	0.003 – 0.01
UO_2 conversion facility											
Ammonia	Rail	960 – 1,120	NA	0	0.0007 – 0.0008	NA	0	0.003	NA	0	0.01 – 0.02
LLW	Truck	360 – 1,680	0.00007 – 0.0003	0	0.0004 – 0.002	0.0003 – 0.001	0	0.002 – 0.008	0.001 – 0.006	0	0.008 – 0.04
LLMW	Truck	20 – 40	2×10^{-8} – 5×10^{-8}	0	0.00002 – 0.00005	1×10^{-7} – 2×10^{-7}	0	0.00009 – 0.0002	5×10^{-7} – 1×10^{-6}	0	0.0005 – 0.0009
HF	Rail	0 – 4,860	NA	0	0 – 0.004	NA	0	0 – 0.01	NA	0	0 – 0.07
CaF_2	Truck	460 – 19,760	NA	0	0.0005 – 0.02	NA	0	0.002 – 0.09	NA	0	0.01 – 0.5
	Rail	180 – 7,300	NA	0	0.0001 – 0.005	NA	0	0.0005 – 0.02	NA	0	0.003 – 0.01

TABLE J.5 (Cont.)

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Facility/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF
Uranium metal conversion facility											
Ammonia	Rail	920	NA	0	0.0007	NA	0	0.003	NA	0	0.01
LLW	Truck	360 – 3,840	0.00003 – 0.004	0	0.0004 – 0.004	0.0001 – 0.02	0	0.002 – 0.02	0.0006 – 0.08	0	0.008 – 0.09
LLMW	Truck	20	2×10^{-8} – 7×10^{-8}	0	0.00002	1×10^{-7} – 3×10^{-7}	0	0.00009	5×10^{-7} – 1×10^{-6}	0	0.0005
HF	Rail	1,640	NA	0	0.001	NA	0	0.005	NA	0	0.02
MgF_2	Truck	10,320 – 10,780	NA	0	0.01	NA	0	0.05	NA	0	0.2 – 0.3
	Rail	3,800 – 3,980	NA	0	0.003	NA	0	0.01	NA	0	0.06
Cylinder treatment facility											
U_3O_8	Truck	22	0.00004	0	0.00003	0.0002	0	0.0001	0.0008	0	0.0005
LLW	Truck	88	3×10^{-7}	0	0.0001	1×10^{-6}	0	0.0004	5×10^{-6}	0	0.002
LLMW	Truck	20	4×10^{-9}	0	0.00002	2×10^{-8}	0	0.00009	8×10^{-8}	0	0.0005

[a] Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

[b] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

[c] Potential for irreversible adverse effects from chemical exposures. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997). Exposure to ammonia was estimated to result in fatality for approximately 2% or less of those persons experiencing irreversible adverse effects.

[d] Includes the estimate for additional cylinders required to handle the depleted uranium in overfilled containers.

TABLE J.6 Total Accident Shipment Risks for the Transportation of Materials for the Cylinder Preparation and Conversion Options

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Facility/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities
Cylinder transfer facility											
LLW	Truck	460 – 580	1×10^{-9} – 2×10^{-9}	0	0.004 – 0.006	5×10^{-9} – 6×10^{-9}	0	0.02	3×10^{-8}	0	0.1
LLMW	Truck	20	1×10^{-12}	0	0.0002	5×10^{-12}	0	0.0009	2×10^{-11}	0	0.004
Depleted UF_6 cylinders[d]											
Paducah	Truck	28,513	0.00008	5×10^{-6}	0.3	0.0003	0.00002	1	0.002	0.0001	6
	Rail	7,129	0.00001	2×10^{-7}	0.08	0.00004	7×10^{-7}	0.3	0.0002	4×10^{-6}	2
Portsmouth	Truck	13,421	0.00004	2×10^{-6}	0.1	0.0002	0.00001	0.5	0.0008	0.00005	3
	Rail	3,356	5×10^{-6}	8×10^{-8}	0.04	0.00002	3×10^{-7}	0.2	0.0001	2×10^{-6}	0.8
Oak Ridge	Truck	4,732	0.00001	8×10^{-7}	0.05	0.00005	3×10^{-6}	0.2	0.0003	0.00002	0.9
	Rail	1,183	2×10^{-6}	3×10^{-8}	0.01	7×10^{-6}	1×10^{-7}	0.06	0.00003	6×10^{-7}	0.3
UF_6 with overcontainers											
Paducah	Truck	28,351	0.00008	5×10^{-6}	0.3	0.0003	0.00002	1	0.002	0.0001	6
	Rail	7,088	0.00001	2×10^{-7}	0.08	0.00004	7×10^{-7}	0.3	0.0002	4×10^{-6}	2
Portsmouth	Truck	13,388	0.00004	2×10^{-6}	0.1	0.0002	0.00001	0.5	0.0008	0.00005	3
	Rail	3,347	5×10^{-6}	8×10^{-8}	0.04	0.00002	3×10^{-7}	0.2	0.0001	2×10^{-6}	0.8
Oak Ridge	Truck	4,683	0.00001	8×10^{-7}	0.05	0.00005	3×10^{-6}	0.2	0.0003	0.00002	0.9
	Rail	1,171	2×10^{-6}	3×10^{-8}	0.01	7×10^{-6}	1×10^{-7}	0.06	0.00003	6×10^{-7}	0.3

TABLE J.6 (Cont.)

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Facility/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities
U_3O_8 conversion facility											
Ammonia	Truck	0 – 520	NA	0 – 0.1	0 – 0.005	NA	0 – 0.6	0 – 0.02	NA	0 – 3	0 – 0.1
LLW	Truck	320 – 1,420	2×10^{-7} – 7×10^{-7}	0	0.003 – 0.01	7×10^{-7} – 3×10^{-6}	0	0.01 – 0.06	3×10^{-6} – 0.00001	0	0.06 – 0.3
LLMW	Truck	20	7×10^{-11}	0	0.0002	3×10^{-10}	0	0.0008	1×10^{-9}	0	0.004
HF	Rail	0 – 4,860	NA	0 – 5	0 – 0.06	NA	0 – 20	0 – 0.2	NA	0 – 100	0 – 1
CaF_2	Truck	460 – 19,760	NA	0	0.005 – 0.2	NA	0	0.02 – 0.8	NA	0	0.09 – 4
	Rail	180 – 7,300	NA	0	0.002 – 0.09	NA	0	0.008 – 0.3	NA	0	0.04 – 2.0
UO_2 conversion facility											
Ammonia	Rail	960 – 1,120	NA	0.1	0.01	NA	0.5	0.05	NA	2 – 3	0.2 – 0.3
LLW	Truck	360 – 1,680	5×10^{-7} – 2×10^{-6}	0	0.004 – 0.02	2×10^{-6} – 8×10^{-6}	0	0.01 – 0.07	0.00001 – 0.00004	0	0.07 – 0.3
LLMW	Truck	20 – 40	7×10^{-11} – 3×10^{-10}	0	0.0002 – 0.0004	3×10^{-10} – 1×10^{-9}	0	0.0008 – 0.002	1×10^{-9} – 7×10^{-9}	0	0.004 – 0.008
HF	Rail	0 – 4,860	NA	0 – 5	0 – 0.06	NA	0 – 20	0 – 0.2	NA	0 – 100	0 – 1
CaF_2	Truck	460 – 19,760	NA	0	0.005 – 0.2	NA	0	0.02 – 0.8	NA	0	0.09 – 4
	Rail	180 – 7,300	NA	0	0.002 – 0.09	NA	0	0.008 – 0.3	NA	0	0.04 – 2.0

TABLE J.6 (Cont.)

Facility/Material	Mode	Total Shipments[a]	Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
			Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities
Uranium metal conversion facility											
Ammonia	Rail	920	NA	0.1	0.01	NA	0.4	0.04	NA	2	0.2
LLW	Truck	360 – 3,840	4×10^{-8} – 3×10^{-6}	0	0.004 – 0.04	1×10^{-7} – 0.00001	0	0.01 – 0.2	7×10^{-7} – 0.00006	0	0.07 – 0.8
LLMW	Truck	20	7×10^{-11}	0	0.0002	3×10^{-10}	0	0.0008	1×10^{-9}	0	0.004
HF	Rail	1,640	NA	2	0.02	NA	7	0.08	NA	30	0.4
MgF_2	Truck	10,320 – 10,780	NA	0	0.1	NA	0	0.4	NA	0	2
	Rail	3,800 – 3,980	NA	0	0.04 – 0.05	NA	0	0.2	NA	0	0.9
Cylinder treatment facility											
U_3O_8	Truck	22	1×10^{-6}	2×10^{-8}	0.0002	6×10^{-6}	7×10^{-8}	0.0009	0.00003	4×10^{-7}	0.004
LLW	Truck	88	7×10^{-10}	0	0.0009	3×10^{-9}	0	0.003	1×10^{-8}	0	0.02
LLMW	Truck	20	3×10^{-11}	0	0.0002	1×10^{-10}	0	0.0008	7×10^{-10}	0	0.004

[a] Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

[b] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

[c] Potential for irreversible adverse effects from chemical exposures. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997). Exposure to ammonia was estimated to result in fatality for approximately 2% or less of those persons experiencing irreversible adverse effects.

[d] Includes the estimate for additional cylinders required to handle the depleted uranium in overfilled containers.

TABLE J.7 Consequences to the MEI from Routine Shipment of Depleted Uranium Materials

		Routine Radiological Risk from Single Shipment (Lifetime Risk of LCF[a])				
Facility/Material	Mode	Inspector	Resident	Person in Traffic	Person at Gas Station	Person near Rail Stop
Cylinder transfer facility						
LLW	Truck	2×10^{-9}	2×10^{-13}	6×10^{-9}	3×10^{-10}	NA
LLMW	Truck	9×10^{-11}	9×10^{-15}	3×10^{-10}	1×10^{-11}	NA
Depleted UF_6	Truck	3×10^{-8}	3×10^{-12}	1×10^{-7}	4×10^{-9}	NA
	Rail	6×10^{-8}	8×10^{-12}	1×10^{-7}	NA	5×10^{-10}
UF_6 with overcontainer	Truck	2×10^{-8}	1×10^{-12}	6×10^{-8}	2×10^{-9}	NA
	Rail	3×10^{-8}	3×10^{-12}	6×10^{-8}	NA	2×10^{-10}
U_3O_8 conversion facility						
LLW	Truck	2×10^{-9}	2×10^{-13}	6×10^{-9} – 8×10^{-9}	3×10^{-10}	NA
LLMW	Truck	9×10^{-11}	9×10^{-15}	3×10^{-10}	1×10^{-11}	NA
UO_2 conversion facility						
LLW	Truck	2×10^{-9} – 5×10^{-9}	2×10^{-13} – 5×10^{-13}	6×10^{-9} – 2×10^{-8}	3×10^{-10} – 7×10^{-10}	NA
LLMW	Truck	9×10^{-11}	9×10^{-15}	3×10^{-10}	1×10^{-11}	NA
Uranium metal conversion facility						
LLW	Truck	2×10^{-9} – 3×10^{-8}	2×10^{-13} – 3×10^{-12}	7×10^{-9} – 8×10^{-8}	3×10^{-10} – 4×10^{-9}	NA
LLMW	Truck	9×10^{-11}	9×10^{-15}	3×10^{-10}	1×10^{-11}	NA
Cylinder treatment facility						
U_3O_8	Truck	6×10^{-8}	5×10^{-12}	2×10^{-7}	7×10^{-9}	NA
LLW	Truck	8×10^{-11}	8×10^{-15}	2×10^{-10}	1×10^{-11}	NA
LLMW	Truck	1×10^{-11}	1×10^{-15}	5×10^{-11}	2×10^{-12}	NA
U_3O_8	Truck	6×10^{-8}	5×10^{-12}	2×10^{-7}	7×10^{-9}	NA
	Rail	7×10^{-8}	8×10^{-12}	2×10^{-7}	NA	5×10^{-10}
UO_2	Truck	5×10^{-8}	4×10^{-12}	2×10^{-7}	6×10^{-9}	NA
	Rail	6×10^{-8}	5×10^{-12}	2×10^{-7}	NA	3×10^{-10}
Uranium metal	Truck	1×10^{-8}	8×10^{-13} – 9×10^{-13}	3×10^{-8} – 4×10^{-8}	1×10^{-9}	NA
	Rail	1×10^{-8}	1×10^{-12}	3×10^{-8} – 4×10^{-8}	NA	7×10^{-11} – 8×10^{-11}
Uranium oxide casks						
LLW	Truck	1×10^{-8}	1×10^{-12}	3×10^{-8}	1×10^{-9}	NA
LLMW	Truck	1×10^{-9}	1×10^{-13}	4×10^{-9}	2×10^{-10}	NA
Cask	Rail	2×10^{-8}	2×10^{-12}	8×10^{-8}	NA	1×10^{-10}
Uranium metal casks						
LLW	Truck	2×10^{-9}	2×10^{-13}	5×10^{-9}	2×10^{-10}	NA
LLMW	Truck	5×10^{-9}	5×10^{-13}	1×10^{-8}	7×10^{-10}	NA
Cask	Rail	1×10^{-8}	1×10^{-12}	4×10^{-8}	NA	6×10^{-11}

[a] Lifetime risk of LCF for an individual was estimated from the calculated dose using the dose-to-risk conversion factor of 0.0005 fatalities per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the risk of LCF by 2,000 (i.e., 1 ÷ 0.0005).

TABLE J.8 Potential Radiological Consequences to the Population from Severe Accidents Involving Shipment of Materials for the Cylinder Preparation and Conversion Options

		Radiological Risk (LCF[a])					
		Neutral Weather Conditions			Stable Weather Conditions		
Facility/Material	Mode	Rural	Suburban	Urban	Rural	Suburban	Urban
Cylinder transfer facility							
LLW	Truck	0.0002	0.0002	0.0004	0.0004	0.0004	0.0009
LLMW	Truck	4×10^{-6}	4×10^{-6}	8×10^{-6}	9×10^{-6}	9×10^{-6}	0.00002
Depleted UF_6	Truck	0.3	0.3	0.6	7	7	20
	Rail	1	1	3	30	30	60
U_3O_8 conversion facility							
LLW	Truck	0.0008 – 0.0009	0.0008 – 0.0009	0.002	0.002	0.002	0.004 – 0.005
LLMW	Truck	6×10^{-6}	5×10^{-6}	0.00001	0.00001	0.00001	0.00003
UO_2 conversion facility							
LLW	Truck	0.001 – 0.002	0.001 – 0.002	0.003 – 0.005	0.003 – 0.006	0.003 – 0.006	0.007 – 0.01
LLMW	Truck	0.00001 – 6×10^{-6}	0.00001 – 6×10^{-6}	0.00001 – 0.00003	0.00001 – 0.00003	0.00001 – 0.00003	0.00003 – 0.00007
Uranium metal conversion facility							
LLW	Truck	0.0005 – 0.002	0.0005 – 0.002	0.001 – 0.004	0.001 – 0.004	0.001 – 0.004	0.003 – 0.009
LLMW	Truck	6×10^{-6}	5×10^{-6}	0.00001	0.00001	0.00001	0.00003
Cylinder treatment facility							
U_3O_8	Truck	0.1	0.1	0.2	0.3	0.2	0.5
LLW	Truck	0.00001	0.00001	0.00003	0.00003	0.00003	0.00007
LLMW	Truck	3×10^{-6}	3×10^{-6}	6×10^{-6}	7×10^{-6}	6×10^{-6}	0.00001

[a] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

TABLE J.9 Potential Chemical Consequences to the Population from Severe Accidents Involving Shipment of Materials for the Cylinder Preparation and Conversion Options

		Number of Persons with Potential for Irreversible Adverse Effects[a]					
		Neutral Weather Conditions			Stable Weather Conditions		
Facility/Material	Mode	Rural	Suburban	Urban	Rural	Suburban	Urban
Cylinder transfer facility							
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0
Depleted UF_6	Truck	0	1	2	0	1	3
	Rail	0	1	3	0	2	4
U_3O_8 conversion facility							
Ammonia	Truck	0 – 1	0 – 100	0 – 200	0 – 10	0 – 1,000	0 – 3,000
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0
HF	Rail	0 – 10	0 – 1,000	0 – 3,000	0 – 100	0 – 10,000	0 – 30,000
UO_2 conversion facility							
Ammonia	Rail	1	200	400	20	2,000	5,000
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0
HF	Rail	0 – 10	0 – 1,000	0 – 3,000	0 – 100	0 – 10,000	0 – 30,000
Uranium metal conversion facility							
Ammonia	Rail	1	200	400	20	2,000	5,000
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0
HF	Rail	10	1,000	3,000	100	10,000	30,000
Cylinder treatment facility							
U_3O_8	Truck	0	0	0	0	4	8
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0

[a] Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997). Exposure to ammonia was estimated to result in fatality for approximately 2% or less of those persons experiencing irreversible adverse effects.

TABLE J.10 Potential Consequences to the MEI from Severe Accidents Involving Shipment of Materials for the Cylinder Preparation and Conversion Options

		Accident Risk			
		Neutral Weather Conditions		Stable Weather Conditions	
Facility/Material	Mode	Radiological Risk of LCF[a]	Chemical Effects[b]	Radiological Risk of LCF[a]	Chemical Effects[b]
Cylinder transfer facility					
LLW	Truck	7×10^{-6}	No	0.0001	No
LLMW	Truck	2×10^{-7}	No	2×10^{-6}	No
Depleted UF_6	Truck	0.0002	Yes	0.0005	Yes
	Rail	0.0009	Yes	0.002	Yes
U_3O_8 conversion facility					
Ammonia	Truck	NA	Yes	NA	Yes
LLW	Truck	0.00003 – 0.00004	No	0.0006	No
LLMW	Truck	2×10^{-7}	No	4×10^{-6}	No
HF	Rail	NA	Yes	NA	Yes
UO_2 conversion facility					
Ammonia	Rail	NA	Yes	NA	Yes
LLW	Truck	0.00006 – 0.0001	No	0.0009 – 0.002	No
LLMW	Truck	$2 \times 10^{-7} - 6 \times 10^{-7}$	No	$4 \times 10^{-6} - 9 \times 10^{-6}$	No
HF	Rail	NA	Yes	NA	Yes
Uranium metal conversion facility					
Ammonia	Rail	NA	Yes	NA	Yes
LLW	Truck	0.00002 – 0.00007	No	0.0004 – 0.001	No
LLMW	Truck	2×10^{-7}	No	4×10^{-6}	No
HF	Rail	NA	Yes	NA	Yes
Cylinder treatment facility					
U_3O_8	Truck	0.004	Yes	0.07	Yes
LLW	Truck	6×10^{-7}	No	9×10^{-6}	No
LLMW	Truck	1×10^{-7}	No	2×10^{-6}	No

[a] Lifetime risk of LCF for an individual was estimated from the calculated doses using a dose-to-risk conversion factor of 5×10^{-4} fatality per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,000 (i.e., $1 \div 0.0005$).

[b] Yes or No applies to the effect of chemical exposure on the MEI. There is no probability estimate; either there would or would not be an irreversible adverse effect. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997). Exposure to ammonia was estimated to result in fatality for approximately 2% or less of those persons experiencing irreversible adverse effects.

Transportation impacts associated with the cylinder transfer facility would be very small. No vehicle-related fatalities would be expected (< 1), and the vehicle-related risks would be about 10 times higher than the radiological risks. No radiological fatalities or irreversible adverse chemical effects would be expected as a result of a potential severe accident. The highest potential routine radiological exposure to an MEI, with a latent cancer fatality risk of 6×10^{-9}, would occur for a person stopped in traffic near a shipment for 30 minutes at a distance of 3.3 ft (1 m). Such an exposure would be about 100 times less than the exposure a person receives from natural sources in the course of 1 day.

J.3.4 Conversion Options

The conversion options would involve transportation of the depleted UF_6 cylinders from their current locations at the three storage sites to a conversion facility, transportation of any chemicals required by the conversion process, and transportation of the waste materials to a disposal site. Transportation of the conversion products is included in the discussion of the long-term storage, manufacture and use, and disposal options in Appendices G, H, and I of this PEIS.

The total collective radiological risks (i.e., the total risks to all workers and members of the public potentially exposed) associated with transportation of the depleted UF_6 cylinders; conversion to U_3O_8, UO_2, and metal; and the cylinder treatment facility are summarized in Tables J.5 and J.6 for routine and accident risks, respectively. Table J.7 summarizes the routine risks to MEIs, and Tables J.8 and J.9 summarize the potential severe accident consequences to local populations from radiological and chemical hazards, respectively. Table J.10 summarizes the accident consequences to MEIs.

J.3.4.1 Transportation of Depleted UF_6

The initial step in the conversion process would be to deliver the depleted UF_6 from the three storage sites to the conversion facility. The cylinders would be prepared for transport at each site, as discussed in Section J.3.3, and shipped to the conversion facility location. Shipment of all cylinders by both truck or rail has been assessed. Rail shipments would consist of four cylinders per railcar, whereas truck shipments would involve only one cylinder per truck. Because the number of cylinders that might require overcontainers is uncertain at this time, impacts were assessed for two bounding cases: under the first case, the depleted UF_6 would be transferred from nonconforming cylinders to new cylinders before transport; under the second case, all cylinders would be shipped in protective overcontainers. Risks for a given combination of cylinder shipments with and without overcontainers can be obtained by a linear interpolation between the two cases.

Protective overcontainers would reduce the external radiation emanating from the shipments by a factor of almost two. Because the radiological risk would be dominated by exposure during routine transport, the radiological risk from shipments with overcontainers would also be about half the value for shipments without overcontainers. On the other hand, shipment of the depleted UF_6 cylinders in overcontainers is not expected to provide additional protection under severe accident conditions. Therefore, the risks from shipment of cylinders with and without overcontainers would be expected to be the same for severe accidents.

The chemical risk associated with cylinder transport would be much less than the radiological risk; however, the total risks would be dominated by vehicle-related risks, which would be about 10 times larger than the radiological and chemical risks combined. Thus, risks from transport by rail appear to be slightly less than the truck risks because of higher shipment capacities and therefore fewer shipments.

Impacts from a potential severe accident could lead to fatalities from both radiological and chemical effects. Up to 60 potential latent cancer fatalities from radiological hazards are estimated for a rail accident occurring in an urban population zone under stable weather conditions. On the basis of chemical toxicity effects for the same conditions, up to 4 persons could be affected by irreversible adverse effects.

The highest potential routine radiological exposure to an MEI, with a latent cancer fatality risk of 1×10^{-7}, would be for a person stopped in traffic near a shipment for 30 minutes at a distance of 3.3 ft (1 m). Such an exposure would be approximately 5 times less than the exposure a person receives from natural sources in the course of 1 day.

J.3.4.2 Conversion to U_3O_8, UO_2, or Metal

Conversion of the depleted UF_6 to the U_3O_8 or UO_2 oxide forms was assessed for both long-term storage (Appendix G) and disposal (Appendix I); conversion to UO_2 or metal was also assessed for use in cask manufacture (Appendix H). Transportation of other materials related to the conversion process would include the ammonia used in the conversion processes and the LLW, LLMW, and HF by-products of the conversion processes.

The total transportation risks associated with the conversion process would be low for all three conversion processes. The LLW and LLMW shipments to disposal would pose no irreversible adverse chemical effects, and the radiological risks would be about 100 times less than the vehicle-related risks. The largest risks would be associated with the chemical hazards associated with transportation of the HF by-product. These risks would be about 100 times the vehicle-related risks.

No radiological fatalities would be expected as a result of a potential severe accident. A severe accident involving ammonia or HF could result in fatalities, with a potential for approximately 30,000 persons to experience irreversible adverse effects from an accident involving HF under stable conditions in an urban area. However, the overall probability of an anhydrous HF accident occurring would depend on the total number of shipments and the actual locations of the origin and destination sites. The probability of an accident would increase with the number of shipments and distance between sites. Approximately 5,000 railcars of anhydrous HF would be produced if the entire UF_6 inventory were converted to oxide. Assuming the distance traveled per shipment is 620 miles (1,000 km) and based on national average accident statistics for railcars, the overall probability for such an accident in an urban area would be about 3×10^{-5} (about 1 chance in 30,000) over the duration of the program. The resulting overall risk to the public (defined as the product of the accident consequence and the probability) would be 1 irreversible adverse effect (i.e, about 1 person would be expected to experience irreversible adverse effects) due to HF-related transportation accidents. This calculation assumes that the accident would occur in an urban area under weather conditions that result in maximum consequences. Further discussion on potential severe anhydrous HF accidents is presented in Chapter 5, Section 5.2.2.2.

The risk of latent cancer fatality to an MEI from a single routine radiological exposure to a given shipment would be negligible. The highest potential exposure, with an LCF risk of 6×10^{-9}, would occur for a person stopped in traffic near a shipment for 30 minutes at a distance of 3.3 ft (1 m). Such an exposure would be approximately 100 times less than the exposure a person receives from natural sources in the course of 1 day.

J.3.4.3 Cylinder Treatment Facility

After the depleted UF_6 cylinders were "emptied" at the conversion facility, they would still retain approximately 22 lb (10 kg) of UF_6, which corresponds to the amount remaining in the cylinder in the vapor phase at autoclave pressure and temperature (Charles et al. 1991). A cylinder treatment facility was assumed to be colocated with the conversion facility to clean and decontaminate the cylinders once they had been emptied. Therefore, the only chemical or radioactive material transportation risks would be from small amounts of U_3O_8, LLW, and LLMW generated at the facility. It was assumed that the cleaned cylinders would be placed in the scrap metal pile at the conversion site.

No fatalities would be expected due to transportation of materials from the cylinder treatment facility. The highest potential routine radiological exposure, with a latent cancer fatality risk of 2×10^{-7}, would occur for a person stopped in traffic near a shipment of U_3O_8 for 30 minutes at a distance of 3.3 ft (1 m) if it were shipped to a disposal site. Such an exposure would be less than half the radiological exposure that a person receives from natural sources in the course of 1 day.

Less than one radiological latent cancer fatality might be expected as a result of a potential severe accident involving shipment of U_3O_8 under stable weather conditions. Because of the chemical toxicity of the uranium oxide, approximately 8 persons could experience irreversible adverse effects in an urban area under stable weather conditions.

J.3.5 Long-Term Storage Options

Three options were assessed for long-term storage of depleted uranium compounds at a single location. The depleted uranium could be stored in its current form as depleted UF_6 or converted to an oxide form (UO_2 or U_3O_8) and then stored. Transportation impacts related to conversion of the depleted UF_6 to the oxide forms are discussed in Section J.3.4.2. Potential impacts from transportation of the depleted uranium material in its final form to a long-term storage site are discussed in this section.

Small amounts of waste could be generated due to container failure during the surveillance phase of the long-term storage options. The impacts of transporting this waste to a disposal site was not considered because the number of associated shipments would be less than one per year (LLNL 1997).

The estimated impacts associated with transportation for the long-term storage options are presented in Tables J.11 through J.14. The total collective radiological risks (i.e., the total risk to all workers and members of the public potentially exposed) are summarized in Tables J.11 and J.12 for routine and accident risks, respectively. Table J.7 summarizes the routine risks to MEIs, and Tables J.13 and J.14 summarize the potential severe accident consequences to local populations and MEIs, respectively.

J.3.5.1 Storage as Depleted UF_6

Long-term storage of depleted UF_6 at a single storage site would involve shipping the depleted UF_6 cylinders from their current locations at the three existing storage sites. The potential transportation impacts from shipping these depleted UF_6 cylinders to a storage facility would be the same as for shipping to a conversion facility (Section J.3.4.1).

J.3.5.2 Storage as U_3O_8 or UO_2

Long-term storage of depleted uranium as U_3O_8 or UO_2 would involve shipping the oxide from a single conversion facility to the storage site. The same impacts would also be incurred from shipping the oxide from a conversion facility or storage site to a disposal site (Section J.3.7) or to a cask manufacturing facility (Section J.3.6).

The radiological risk associated with shipping all of the U_3O_8 or UO_2 to a storage site from a conversion facility would be larger than the chemical risk, but the total risks would still be dominated by vehicle-related risks, which would be about 10 times larger than the radiological risks. Therefore, risks from rail transport would be less than risks from truck transport because of higher shipment capacities and therefore fewer shipments.

TABLE J.11 Total Routine Shipment Risks for the Transportation of Materials for Long-Term Storage

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Facility/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF
Depleted UF_6 cylinders[d]											
Paducah	Truck	28,513	0.02	0	0.03	0.08	0	0.1	0.4	0	0.7
	Rail	7,129	0.01	0	0.005	0.02	0	0.02	0.06	0	0.1
Portsmouth	Truck	13,421	0.009	0	0.02	0.04	0	0.06	0.2	0	0.3
	Rail	3,356	0.005	0	0.003	0.008	0	0.01	0.03	0	0.05
Oak Ridge	Truck	4,732	0.003	0	0.006	0.01	0	0.02	0.06	0	0.1
	Rail	1,183	0.002	0	0.0009	0.003	0	0.004	0.01	0	0.02
UF_6 with overcontainers											
Paducah	Truck	28,351	0.01	0	0.03	0.04	0	0.1	0.2	0	0.7
	Rail	7,088	0.009	0	0.005	0.01	0	0.02	0.03	0	0.1
Portsmouth	Truck	13,388	0.005	0	0.02	0.02	0	0.06	0.09	0	0.3
	Rail	3,347	0.004	0	0.003	0.006	0	0.01	0.01	0	0.05
Oak Ridge	Truck	4,683	0.002	0	0.005	0.006	0	0.02	0.03	0	0.1
	Rail	1,171	0.001	0	0.0009	0.002	0	0.004	0.005	0	0.02
U_3O_8	Truck	25,500	0.05	0	0.03	0.2	0	0.1	0.9	0	0.6
	Rail	8,960	0.02	0	0.007	0.03	0	0.03	0.09	0	0.1
UO_2	Truck	26,260 – 26,800	0.04	0	0.03	0.2	0	0.1	0.8	0	0.6
	Rail	8,480 – 8,800	0.01	0	0.006 – 0.007	0.02	0	0.03	0.06	0	0.1

[a] Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

[b] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

[c] Potential for irreversible adverse effects from chemical exposures. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

[d] Includes the estimate for additional cylinders required to handle the depleted uranium in overfilled containers.

TABLE J.12 Total Accident Shipment Risks for the Transportation of Materials for Long-Term Storage

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Facility/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities	Radiological LCF[b]	Chemical Effects[c]	Vehicular Fatalities
Depleted UF_6 cylinders[d]											
Paducah	Truck	28,513	0.00008	5×10^{-6}	0.3	0.0003	0.00002	1	0.002	0.0001	6
	Rail	7,129	0.00001	2×10^{-7}	0.08	0.00004	7×10^{-7}	0.3	0.0002	4×10^{-6}	2
Portsmouth	Truck	13,421	0.00004	2×10^{-6}	0.1	0.0002	0.00001	0.5	0.0008	0.00005	3
	Rail	3,356	5×10^{-6}	8×10^{-8}	0.04	0.00002	3×10^{-7}	0.2	0.0001	2×10^{-6}	0.8
Oak Ridge	Truck	4,732	0.00001	8×10^{-7}	0.05	0.00005	3×10^{-6}	0.2	0.0003	0.00002	0.9
	Rail	1,183	2×10^{-6}	3×10^{-8}	0.01	7×10^{-6}	1×10^{-7}	0.06	0.00003	6×10^{-7}	0.3
UF_6 with overcontainers											
Paducah	Truck	28,351	0.00008	5×10^{-6}	0.3	0.0003	0.00002	1	0.002	0.0001	6
	Rail	7,088	0.00001	2×10^{-7}	0.08	0.00004	7×10^{-7}	0.3	0.0002	4×10^{-6}	2
Portsmouth	Truck	13,388	0.00004	2×10^{-6}	0.1	0.0002	0.00001	0.5	0.0008	0.00005	3
	Rail	3,347	5×10^{-6}	8×10^{-8}	0.04	0.00002	3×10^{-7}	0.2	0.0001	2×10^{-6}	0.8
Oak Ridge	Truck	4,683	0.00001	8×10^{-7}	0.05	0.00005	3×10^{-6}	0.2	0.0003	0.00002	0.9
	Rail	1,171	2×10^{-6}	3×10^{-8}	0.01	7×10^{-6}	1×10^{-7}	0.06	0.00003	6×10^{-7}	0.3
U_3O_8	Truck	25,500	0.002	0.00002	0.3	0.006	0.00009	1	0.03	0.0004	5
	Rail	8,960	0.0004	0.00002	0.1	0.001	0.00007	0.4	0.007	0.0004	2
UO_2	Truck	26,260 – 26,800	0.002	0 – 5×10^{-6}	0.3	0.006	0 – 0.00002	1	0.03	0 – 0.0001	5
	Rail	8,480 – 8,800	0.0004	3×10^{-6} – 6×10^{-6}	0.1	0.001	0.00001 – 0.00003	0.4	0.007	0.00005 – 0.0001	2

[a] Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

[b] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

[c] Potential for irreversible adverse effects from chemical exposures. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

[d] Includes the estimate for additional cylinders required to handle the depleted uranium in overfilled containers.

TABLE J.13 Potential Consequences to the Population from Severe Accidents Involving Shipment of Materials for Long-Term Storage

		Radiological Risk[a] (LCF)					
		Neutral Weather Conditions			Stable Weather Conditions		
Material	Mode	Rural	Suburban	Urban	Rural	Suburban	Urban
Depleted UF_6	Truck	0.3	0.3	0.6	7	7	20
	Rail	1	1	3	30	30	60
U_3O_8	Truck	0.1	0.1	0.2	0.3	0.2	0.5
	Rail	0.3	0.3	0.6	0.7	0.7	2
UO_2	Truck	0.1	0.1	0.2	0.2	0.2	0.5
	Rail	0.3	0.3	0.6 – 0.7	0.7 – 0.8	0.7	2

		Chemical Risk[b] (no. of persons with potential for irreversible adverse effects)					
		Neutral Weather Conditions			Stable Weather Conditions		
Material	Mode	Rural	Suburban	Urban	Rural	Suburban	Urban
Depleted UF_6	Truck	0	1	2	0	1	3
	Rail	0	1	3	0	2	4
U_3O_8	Truck	0	0	0	0	4	8
	Rail	0	1	1	0	10	20
UO_2	Truck	0	0	0	0	1	2
	Rail	0	0	0	0	3	8

[a] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

[b] Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

TABLE J.14 Potential Consequences to the MEI from Severe Accidents Involving Shipment of Materials for Long-Term Storage

		Accident Risk			
		Neutral Weather Conditions		Stable Weather Conditions	
Material	Mode	Radiological Risk of LCF[a]	Chemical Effects[b]	Radiological Risk of LCF[a]	Chemical Effects[b]
Depleted UF_6	Truck	0.0002	Yes	0.0005	Yes
	Rail	0.0009	Yes	0.002	Yes
UF_6 with overcontainer	Truck	0.0002	Yes	0.0005	Yes
	Rail	0.0009	Yes	0.002	Yes
U_3O_8	Truck	0.004	No	0.07	Yes
	Rail	0.01	Yes	0.2	Yes
UO_2	Truck	0.004	No	0.06	Yes
	Rail	0.01	No	0.2	Yes

[a] Lifetime risk of LCF for an individual was estimated from the calculated doses using a dose-to-risk conversion factor of 5×10^{-4} fatality per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,000 (i.e., $1 \div 0.0005$).

[b] Yes or No applies to the effect of chemical exposure on the MEI. There is no probability estimate; either there would or would not be an irreversible adverse effect. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

The risk of latent cancer fatality to an MEI for a single exposure to a given shipment would be small. The highest potential exposure, with a latent cancer fatality risk of 2×10^{-7}, would occur for a person stopped in traffic near a shipment for 30 minutes at a distance of 3.3 ft (1 m). Such an exposure would be less than half the radiological exposure that a person receives from natural sources in the course of 1 day.

Impacts from a potential severe accident could lead to fatalities from both radiological and chemical effects. Approximately 2 potential latent cancer fatalities from radiological hazards are estimated for a rail accident occurring in an urban population zone under stable weather conditions. Because of the chemical hazard of uranium, an estimated 20 people could experience irreversible adverse effects from chemical toxicity under the same conditions.

J.3.6 Manufacture and Use Options

Two alternative uses of depleted uranium were assessed: manufacture of casks using concrete made with cement and UO_2 and manufacture of casks using uranium metal. Potential impacts would be incurred from transport of the feed material (UO_2 or uranium metal) from a conversion facility to the manufacturing plant, transport of the manufactured cask to an end user, and transport of the small amount of LLW and LLMW expected to be generated at the manufacturing facility to a disposal site. Because of the size of the manufactured casks, cask shipment was assumed to occur by rail only. The shipment risks would be approximately the same for both cask options.

The collective population risks associated with the two manufacture and use options are summarized in Tables J.15 and J.16 for routine and accident risks, respectively. The routine risks to MEIs are summarized in Table J.7, and the accident consequences to MEIs and the population are summarized in Tables J.17 and J.18, respectively.

J.3.6.1 Uranium Oxide Casks

The uranium oxide cask option would involve the use of depleted uranium in the form of high-density UO_2 for the manufacture of depleted uranium concrete for shielding in spent nuclear fuel storage casks. The transportation risks associated with transport of the UO_2 to the cask manufacturing facility would be the same as the risks associated with transport of the UO_2 to a storage site (see Section J.3.5.2). Shipment of the uranium oxide casks to an end user would result in approximately the same overall risks as the UO_2 shipments. No chemical risks would be anticipated for transportation of the fabricated casks, and no radiological fatalities would be expected under severe accident conditions.

J.3.6.2 Uranium Metal Casks

The uranium metal cask option would involve the conversion of depleted UF_6 to uranium metal that would then be fabricated into a cask. Transportation impacts were analyzed for shipment of the uranium metal from a conversion facility to a cask manufacturing facility and shipment of the fabricated cask to an end user. No chemical transportation risks would be expected for this option.

The total radiological risk associated with uranium metal transport would be about a factor of 30 or more less than the vehicle-related risks. Shipment risks for the cask would be about the same as for rail transport of the uranium metal feed material. Risks for the generated waste shipments would be negligible compared with the shipment of uranium metal and casks.

The risk of latent cancer fatality to an MEI for a single exposure to a given shipment would be small. The highest potential routine radiological exposure, with a latent cancer fatality risk of 4×10^{-8}, would occur for a person stopped in traffic near a uranium metal or cask shipment for

TABLE J.15 Total Routine Shipment Risks for the Transportation of Materials for Manufacture and Use

			Risks over 250 km			Risks over 1,000 km			Risks over 5,000 km		
Use/Material	Mode	Total Shipments[a]	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF	Radiological LCF[b]	Chemical Effects[c]	Vehicular LCF
Uranium oxide casks											
UO_2	Truck	26,260 – 26,800	0.04	0	0.03	0.2	0	0.1	0.8	0	0.6
	Rail	8,480 – 8,800	0.01	0	0.006 – 0.007	0.02	0	0.03	0.06	0	0.1
LLW	Truck	300	0.0001	0	0.0003	0.0004	0	0.001	0.002	0	0.006
LLMW	Truck	20	1×10^{-6}	0	0.00002	4×10^{-6}	0	0.00009	0.00002	0	0.0005
Cask	Rail	9,600	0.003	0	0.007	0.005	0	0.03	0.02	0	0.1
Uranium metal casks											
Uranium metal	Truck	20,840 – 21,500	0.006 – 0.007	0	0.02 – 0.03	0.03	0	0.1	0.1	0	0.5
	Rail	7,360 – 7,520	0.002	0	0.006	0.004	0	0.02	0.01	0	0.1
LLW	Truck	1,540	0.0001	0	0.002	0.0004	0	0.007	0.02	0	0.04
LLMW	Truck	20	4×10^{-6}	0	0.00002	0.00001	0	0.00009	0.00007	0	0.0005
Cask	Rail	9,060	0.0002	0	0.007	0.0004	0	0.03	0.001	0	0.1

a Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

b Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

c Potential for irreversible adverse effects from chemical exposures. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

TABLE J.16 Total Accident Shipment Risks for the Transportation of Materials for Manufacture and Use

Use/Material	Mode	Total Shipments[a]	Risks over 250 km: Radiological LCF[b]	Risks over 250 km: Chemical Effects[c]	Risks over 250 km: Vehicular Fatalities	Risks over 1,000 km: Radiological LCF[b]	Risks over 1,000 km: Chemical Effects[c]	Risks over 1,000 km: Vehicular Fatalities	Risks over 5,000 km: Radiological LCF[b]	Risks over 5,000 km: Chemical Effects[c]	Risks over 5,000 km: Vehicular Fatalities
Uranium oxide casks											
UO_2	Truck	26,260 – 26,800	0.002	0 – 5×10^{-6}	0.3	0.006	0 – 0.00002	1	0.03	0 – 0.0001	5
	Rail	8,480 – 8,800	0.0004	3×10^{-6} – 6×10^{-6}	0.1	0.001	0.00001 – 0.00003	0.4	0.007	0.00005 – 0.0001	2
LLW	Truck	300	2×10^{-12}	0	0.003	8×10^{-12}	0	0.1	4×10^{-11}	0	0.06
LLMW	Truck	20	8×10^{-11}	0	0.0002	3×10^{-10}	0	0.0008	2×10^{-9}	0	0.004
Cask	Rail	9,600	4×10^{-9}	0	0.1	1×10^{-8}	0	0.5	7×10^{-8}	0	2
Uranium metal casks											
Uranium metal	Truck	20,840 – 21,500	4×10^{-10}	0	0.2	2×10^{-9}	0	0.8	8×10^{-9}	0	4
	Rail	7,360 – 7,520	9×10^{-11}	0	0.09	4×10^{-10}	0	0.3 – 0.4	2×10^{-9}	0	2
LLW	Truck	1,540	2×10^{-6}	0	0.02	8×10^{-6}	0	0.06	0.00004	0	0.3
LLMW	Truck	20	7×10^{-11}	0	0.0002	3×10^{-10}	0	0.0008	1×10^{-9}	0	0.004
Cask	Rail	9,060	1×10^{-10}	0	0.1	4×10^{-10}	0	0.4	2×10^{-9}	0	2

[a] Risks for rail transport were estimated on a railcar basis; therefore, the number of railcars was used for the total number of rail shipments.

[b] Radiological LCFs were estimated from the calculated doses using dose-to-risk conversion factors of 0.0005 and 0.0004 fatality per person-rem for members of the general public and occupational workers, respectively, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,500 (i.e., 1 ÷ 0.0004).

[c] Potential for irreversible adverse effects from chemical exposures. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

TABLE J.17 Potential Consequences to the MEI from Severe Accidents Involving Shipment of Materials for Manufacture and Use

		Accident Risk			
		Neutral Weather Conditions		Stable Weather Conditions	
Use/Material	Mode	Radiological Risk of LCF[a]	Chemical Effects[b]	Radiological Risk of LCF[a]	Chemical Effects[b]
Uranium oxide casks					
UO_2	Truck	0.004	No	0.06	Yes
	Rail	0.01	No	0.2	Yes
LLW	Truck	2×10^{-6}	No	0.00003	No
LLMW	Truck	2×10^{-7}	No	4×10^{-6}	No
Cask	Rail	0.0004	No	0.006	No
Uranium metal casks					
Uranium metal	Truck	0.0001 – 0.0002	No	0.002	No
	Rail	0.0004	No	0.007	No
LLW	Truck	0.00008	No	0.001	No
LLMW	Truck	2×10^{-7}	No	4×10^{-6}	No
Cask	Rail	0.0004	No	0.006	No

[a] Lifetime risk of LCF for an individual was estimated from the calculated doses using a dose-to-risk conversion factor of 0.0005 fatality per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,000 (i.e., 1 ÷ 0.0005).

[b] Yes or No applies to the effect of chemical exposure on the MEI. There is no probability estimate; either there would or would not be an irreversible adverse effect. Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

30 minutes at a distance of 3.3 ft (1 m). Such an exposure would be approximately 10 times less than the exposure a person receives from natural sources in the course of 1 day.

No fatalities from severe accidents would be expected. The transportation risks associated with the transport of the uranium metal cask would be approximately the same as those for the uranium oxide cask.

J.3.7 Disposal Options

Two options were identified for potential disposal of the depleted uranium: disposal as U_3O_8 or disposal as UO_2. In each case, the uranium oxide form would be transported from a single site, either a conversion facility or a storage site, to a disposal site. The impacts associated with

TABLE J.18 Potential Consequences to the Population from Severe Accidents Involving Shipment of Materials for Manufacture and Use

		Radiological Risk[a] (LCF)					
		Neutral Weather Conditions			Stable Weather Conditions		
Material	Mode	Rural	Suburban	Urban	Rural	Suburban	Urban
Uranium oxide casks							
UO_2	Truck	0.1	0.1	0.2	0.2	0.2	0.5
	Rail	0.3	0.3	0.6 – 0.7	0.7 – 0.8	0.7	2
LLW	Truck	1×10^{-8}	1×10^{-8}	3×10^{-8}	3×10^{-8}	2×10^{-8}	5×10^{-8}
LLMW	Truck	6×10^{-6}	6×10^{-6}	0.00001	0.00001	0.00001	0.00003
Cask	Rail	3×10^{-6}	3×10^{-6}	6×10^{-6}	7×10^{-6}	5×10^{-6}	0.00001
Uranium metal casks							
Uranium metal	Truck	1×10^{-6}	8×10^{-7} – 9×10^{-7}	2×10^{-6}	3×10^{-6}	2×10^{-6}	4×10^{-6} – 5×10^{-6}
	Rail	3×10^{-6} – 4×10^{-6}	2×10^{-6}	5×10^{-6}	8×10^{-6} – 9×10^{-6}	6×10^{-6}	0.00001
LLW	Truck	0.002	0.002	0.004	0.005	0.005	0.01
LLMW	Truck	6×10^{-6}	6×10^{-6}	0.00001	0.00001	0.00001	0.00003
Cask	Rail	3×10^{-6}	2×10^{-6}	5×10^{-6}	8×10^{-6}	5×10^{-6}	0.00001

		Chemical Risk[b] (no. of persons with potential for irreversible adverse effects)					
		Neutral Weather Conditions			Stable Weather Conditions		
Material	Mode	Rural	Suburban	Urban	Rural	Suburban	Urban
Uranium oxide casks							
UO_2	Truck	0	0	0	0	1	2
	Rail	0	0	0	0	3	8
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0
Cask	Rail	0	0	0	0	0	0
Uranium metal casks							
Uranium metal	Truck	0	0	0	0	0	0
	Rail	0	0	0	0	0	0
LLW	Truck	0	0	0	0	0	0
LLMW	Truck	0	0	0	0	0	0
Cask	Rail	0	0	0	0	0	0

[a] Radiological LCFs were estimated from the calculated doses using a dose-to-risk conversion factor of 0.0005 fatality per person-rem for members of the general public, as recommended in ICRP Publication 60 (ICRP 1991). The approximate corresponding dose received for each radiological fatality risk listed in this table may be obtained by multiplying the fatality risk by 2,000 (i.e., 1 ÷ 0.0005).

[b] Exposure to HF or uranium compounds was estimated to result in fatality for approximately 1% or less of those persons experiencing irreversible adverse effects (Policastro et al. 1997).

transport to a disposal site would be the same as those for transport to a storage site (see Section J.3.5.2). Comparison of the transportation impacts associated with the two disposal options shows no significant difference between the two.

J.3.8 Other Impacts Considered But Not Analyzed in Detail

Other impacts could potentially occur if the transportation options considered in this PEIS were implemented, including impacts to air quality, water quality, ecology, socioeconomics, cultural resources, visual environment (e.g., aesthetics), recreational resources, wetlands, noise levels, and environmental justice issues. These impacts, although considered, were not analyzed in detail for one or more of the following reasons:

- Consideration of the impacts would not contribute to differentiation among the alternatives and therefore would not affect the decisions to be made in the Record of Decision that will be issued following this PEIS.

- The impacts could not be determined at the programmatic level without consideration of specific routes between specific sites. Potential impacts would be more appropriately addressed in the second-tier *National Environmental Policy Act* (NEPA) documentation when specific sites are considered.

J.4 REFERENCES FOR APPENDIX J

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DOE: see U.S. Department of Energy.

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APPENDIX K:

PARAMETRIC ANALYSIS: ENVIRONMENTAL IMPACTS OF CONVERSION, LONG-TERM STORAGE, MANUFACTURE AND USE, AND DISPOSAL OPTIONS FOR PROCESSING LESS THAN THE TOTAL DEPLETED UF_6 INVENTORY

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FIGURES (Cont.)

FIGURES (Cont.)

FIGURES (Cont.)

NOTATION (APPENDIX K)

The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LCF	latent cancer fatality
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LLW	low-level radioactive waste
MEI	maximally exposed individual
NEPA	*National Environmental Policy Act*
PEIS	programmatic environmental impact statement
ROI	region of influence

Chemicals

HF	hydrogen fluoride
MgF_2	magnesium fluoride
NO_x	nitrogen oxides
UF_6	uranium hexafluoride
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide (uranyl uranate)

UNITS OF MEASURE

d	day(s)	mrem	millirem(s)
ft	foot (feet)	MWh	megawatt-hour(s)
ha	hectare(s)	pCi	picocurie(s)
km	kilometer(s)	rad	radiation absorbed dose(s)
L	liter(s)	rem	roentgen equivalent man
μg	microgram(s)	yd^3	cubic yard(s)
m	meter(s)	yr	year(s)
m^3	cubic meter(s)		

APPENDIX K:

PARAMETRIC ANALYSIS: ENVIRONMENTAL IMPACTS OF CONVERSION, LONG-TERM STORAGE, MANUFACTURE AND USE, AND DISPOSAL OPTIONS FOR PROCESSING LESS THAN THE TOTAL DEPLETED UF_6 INVENTORY

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period from 1999 through 2039. This appendix provides detailed information describing the parametric analysis used to assess potential environmental impacts of conversion, long-term storage, manufacture and use, and disposal options considered in the PEIS for processing less than the total depleted UF_6 inventory.

The environmental impacts presented in Chapter 5 of the PEIS are based on the assumption that all facilities would be designed to either convert, store, manufacture and use, or dispose of all of the depleted UF_6 in the DOE inventory. This approach provided a conservative estimate of the impacts that could result from each of the alternatives considered. Detailed discussions of the estimated environmental impacts from processing the entire depleted UF_6 inventory are presented for cylinder preparation, conversion, long-term storage, manufacture and use, disposal, and transportation options in Appendices E through J, respectively. The results of these evaluations are referred to as "100%" cases because they are based on the assumption that all of the depleted UF_6 would be processed (i.e., converted, stored, manufactured and used, disposed of, or transported).

In contrast to the 100% cases, the parametric analysis cases presented in this appendix considered the environmental impacts of each option category if the facilities were designed to process or accommodate only a fraction of the depleted UF_6 inventory (in the event that DOE would select a combination of alternatives to manage the entire inventory; see below). The intent of the parametric analysis was to show how the environmental impacts calculated for the 100% cases would be affected by reductions in facility size and throughput. "Throughput" is a general term that refers to the amount of material handled or processed by a facility in a year. Sections K.2-K.6 of this parametric appendix present the environmental impacts for the conversion, long-term storage, manufacture and use, disposal, and transportation options for facilities designed to process between 25% and 100% of the depleted UF_6 inventory. (The impacts of the cylinder preparation options for various throughputs are addressed in Appendix E.)

The results of the parametric analyses for the individual management components presented in Sections K.2-K.6 can be compiled to estimate the environmental impacts of combinations of alternatives; for example, use of 50% of the inventory as metal and use of 50% of the inventory as oxide. An example calculation of impacts for such a combination of alternatives is provided in Section K.7. Any combination of alternatives selected would result in management of 100% of the depleted UF_6 inventory. The results of the parametric analyses can also be used to estimate the impacts for situations in which more than one site would be used (e.g., conversion to oxide at two locations).

For assessment purposes, the parametric analysis assumed that all facilities would be designed to operate over a 20-year time period (i.e., the period required to process the DOE-generated cylinders, similar to the 100% cases presented in Appendices E through J). Thus, it was assumed that the processing of only a fraction of the DOE depleted UF_6 inventory would be accomplished by building and operating smaller facilities than those required for the 100% cases. In practice, it would be possible to process a fraction of the inventory by operating facilities designed to process 100% of the inventory over 20 years for a reduced time period, such as 10 years, or by operating the facility at a reduced level. In addition, changes in operating schedule could be used to accommodate small changes in the DOE inventory. For example, a 10% increase in the total DOE inventory could be accommodated by operating a full-scale facility for 22 years instead of 20.

For a given option, the environmental impacts resulting from the parametric analysis cases would tend to be less than or equal to those presented for the 100% cases. Thus, if the impacts were negligible for the 100% case, the impacts for the parametric cases would also be negligible. For most areas considered — such as human health and safety during normal operations, water, ecology, resource requirements, waste management, land use, and socioeconomics — the impacts would decrease as the facility size or throughput decreased. However, the reduction in impacts would not always be proportional to the reduction in throughput. For example, a facility designed to process 500 cylinders per year would generally have smaller impacts than a facility designed to process 1,000 cylinders per year, although the impacts would not necessarily be half of those of the larger facility. For accidents producing the greatest consequences, impacts would tend to be the same for the parametric analysis cases and the 100% case, primarily because these types of accidents would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput.

The following sections summarize the approach and results of the parametric analysis. Section K.1 presents a short summary of the assessment approach. The results are presented for the conversion options in Section K.2, for long-term storage options in Section K.3, for manufacture and use options in Section K.4, for disposal options in Section K.5, and for transportation options in Section K.6; parametric assessment results for the cylinder preparation options are provided in Appendix E. Section K.7 presents an example of the calculation of impacts for a specific combination alternative and the summary of impacts for several example combination alternatives.

The discussion in this appendix (Appendix K) does not include details of the assessment methodologies or definitions of the options considered in the PEIS. A detailed description of methodologies is presented in Appendix C, and definitions and descriptions of the option categories are provided in Appendices F through J. Finally, in cases where the impacts from the parametric analysis do not differ significantly from the 100% case, readers are referred to Appendices F through J for additional discussion.

K.1 PARAMETRIC ANALYSIS ASSESSMENT APPROACH

Two parametric cases were analyzed for conversion, long-term storage as oxide, manufacture and use, and disposal options: (1) facilities designed to process or accommodate 50% of the depleted UF_6 inventory; and (2) facilities designed to process or accommodate 25% of the inventory. To simplify the analysis, the parametric cases were analyzed in detail for a subset of options within each option category, as summarized in Table K.1. A subset of options was selected because the relationships among the options within each category could be determined from the detailed analyses conducted for the 100% cases. Therefore, the results for the options analyzed in detail were used to estimate the impacts for all options within each category by comparison with the 100% cases.

The basic assessment approach, areas of impact, and methodologies used to evaluate the parametric cases were the same as those used to evaluate the 100% cases. The environmental impacts for the 100% cases were evaluated using information provided in the engineering analysis report (Lawrence Livermore National Laboratory [LLNL 1997a]), including descriptions of facility layouts; resource requirements; estimates of effluents, wastes, and emissions; and descriptions of potential accident scenarios. To support the parametric assessment, similar design information was used for facilities sized to process or accommodate 25% and 50% of the depleted UF_6 inventory (LLNL 1997a).

The results of the parametric analysis are presented, where appropriate, as curves that show the environmental impacts as a function of facility throughput. The curves were constructed using the results for the 25%, 50%, and 100% cases. These curves can be used to estimate the environmental impacts for throughputs ranging between 25% and 100% of the depleted UF_6 inventory. In addition, the curves can also be used to provide rough estimates of the impacts for throughputs slightly below 25% and slightly above 100%. In cases where the impacts for the 100% case were negligible, the parametric analysis was conducted to confirm that the impacts were also negligible, and only a brief discussion is provided. (The terms used in this PEIS to describe impacts, such as "negligible," are defined in Chapter 4, Table 4.2.)

K.2 CONVERSION OPTIONS

The parametric analysis of the conversion options considered the environmental impacts of converting 25% and 50% of the depleted UF_6 inventory to triuranium octaoxide (U_3O_8), uranium dioxide (UO_2), or uranium metal over a 20-year period. The assessment considered the environmental impacts that would occur during (1) construction of a conversion facility, (2) routine conversion facility operations, and (3) potential conversion facility accidents. The areas of impact and the methodologies used to evaluate the parametric cases were the same as those used to evaluate the 100% cases, the results of which are discussed in Appendix F. The supporting data for the 25% and 50% parametric conversion cases are provided in the engineering analysis report (LLNL 1997a).

TABLE K.1 Specific Options and Parametric Cases Analyzed in Detail

Option Category/ Options Analyzed in Detail	Parametric Cases Analyzed for Each Option	
Conversion	Conversion to U_3O_8, UO_2, and metal:	
	100% case:	Conversion of 100% of the inventory over 20 years
	50% case:	Conversion of 50% of the inventory over 20 years
	25% case:	Conversion of 25% of the inventory over 20 years
Long-term storage		
Storage as UF_6 in buildings	Storage as UF_6:	
	100% case:	Storage of 46,422 cylinders
	50% case:	Storage of 23,211 cylinders
	25% case:	Storage of 11,606 cylinders
Storage as UO_2 in buildings	Storage as UO_2:	
	100% case:	Storage of 420,000 drums
	50% case:	Storage of 210,000 drums
	25% case:	Storage of 105,000 drums
Manufacture and use		
Use as uranium oxide	Use as UO_2:	
	100% case:	Use of 100% of the inventory as oxide shielding
	50% case:	Use of 50% of the inventory as oxide shielding
	25% case:	Use of 25% of the inventory as oxide shielding
Use as uranium metal	Use as metal:	
	100% case:	Use of 100% of the inventory as metal shielding
	50% case:	Use of 50% of the inventory as metal shielding
	25% case:	Use of 25% of the inventory as metal shielding
Disposal		
Disposal as ungrouted U_3O_8 in a mine	100% case:	Disposal of 100% of the inventory over 20 years
	50% case:	Disposal of 50% of the inventory over 20 years
	25% case:	Disposal of 25% of the inventory over 20 years

In general, the impacts for the 100% cases are presented in Appendix F as ranges, resulting from differences in technologies within each option and site differences. For the purposes of the parametric analysis, one technology from each option was considered and evaluated in detail at a representative site. A single technology and a representative site were evaluated for each option to simplify the parametric analysis. This simplification was possible because all technologies were evaluated at all representative sites for the 100% base case. The specific technologies considered were defluorination with anhydrous hydrogen fluoride (HF) production for conversion to U_3O_8; dry defluorination with anhydrous HF production for conversion to UO_2; and continuous metallothermic reduction for conversion to uranium metal. The resulting relationships between the technologies and sites that were identified for the 100% case were used to infer ranges of impacts for the parametric cases examined in detail.

K.2.1 Human Health — Normal Operations

K.2.1.1 Radiological Impacts

The estimated radiological impacts — radiation doses and latent cancer fatalities (LCFs) — from the normal operation of a full-scale (100%) facility for converting depleted UF_6 to U_3O_8 are described in Appendix F, Section F.3.1.1. Similar impacts were calculated for the 50% and 25% conversion facilities for the parametric analysis. The radiological impacts estimated for the 100%, 50%, and 25% case are shown in Figures K.1 through K.6 as the radiation doses for the six receptor scenarios considered in the PEIS:

- Members of the general public
  - Annual collective dose
  - Annual dose to the maximally exposed individual (MEI)

- Noninvolved workers
  - Annual collective dose
  - Annual dose to the MEI

- Involved workers
  - Annual collective dose
  - Annual average individual dose

The ranges of impacts resulting from site and technology differences for each option are represented by dashed lines in the figures. The results for the technology selected for detailed analysis are shown in the figures as solid points, with a curve drawn between the points to indicate how the impacts vary as a function of the percent of depleted UF_6 processed. The upper and lower bounds for impacts for the 25% and 50% cases were estimated on the basis of the range

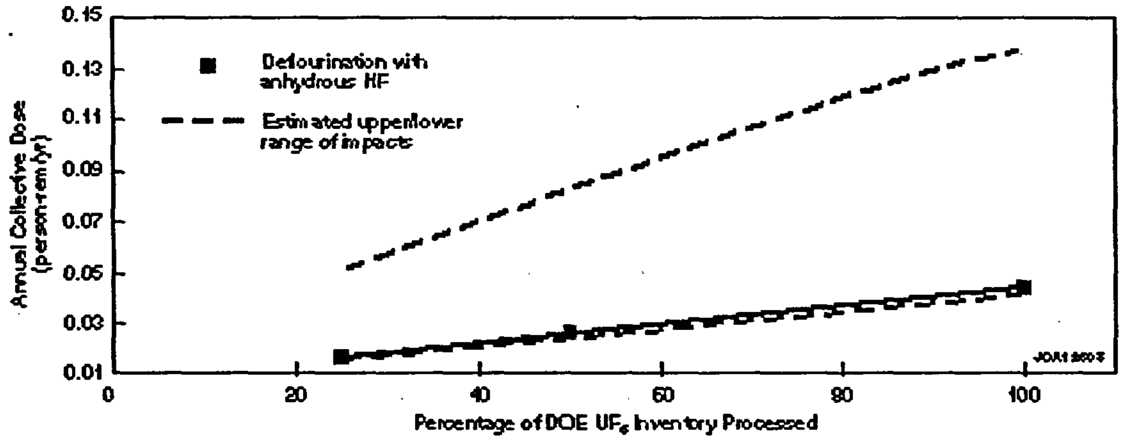

FIGURE K.1 Estimated Annual Collective Dose to Members of the Public from the Conversion of UF_6 to U_3O_8 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

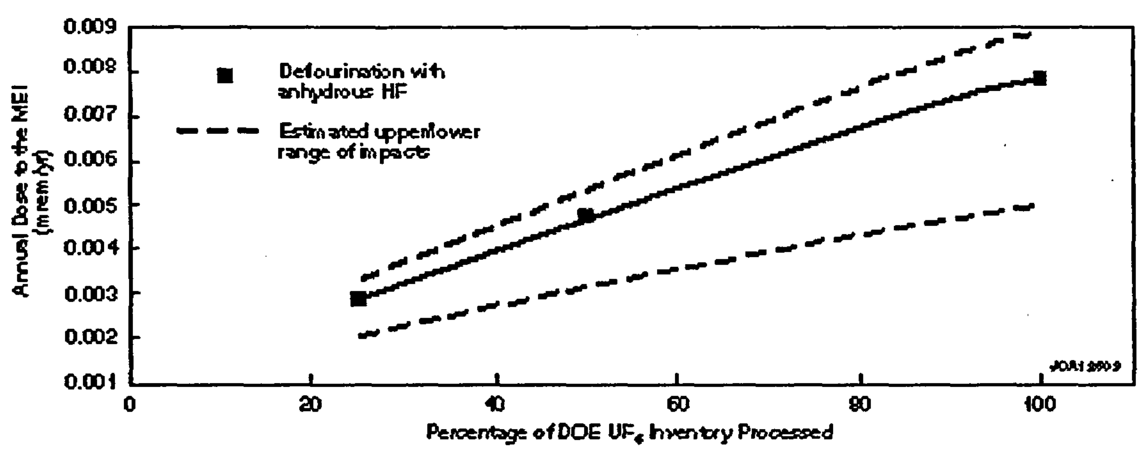

FIGURE K.2 Estimated Annual Dose to the General Public MEI from the Conversion of UF_6 to U_3O_8 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

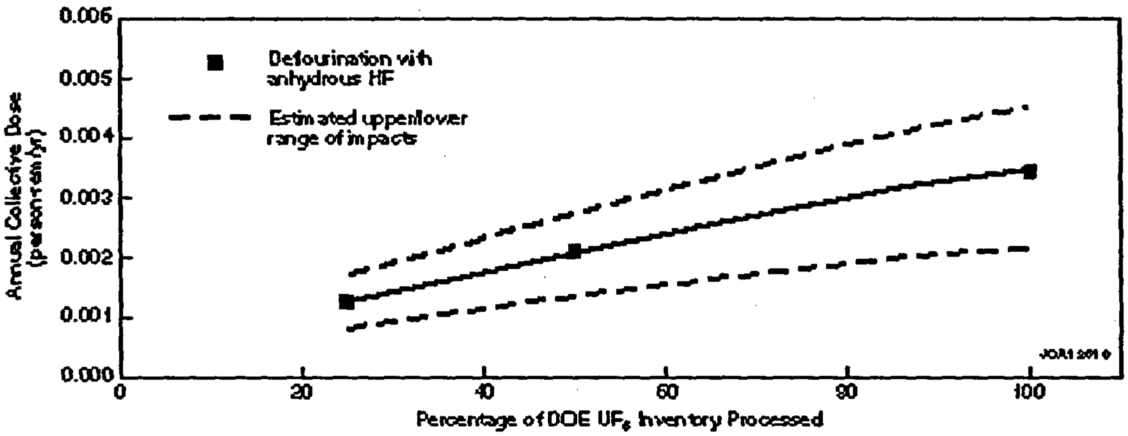

FIGURE K.3 Estimated Annual Collective Dose to Noninvolved Workers from the Conversion of UF_6 to U_3O_8 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

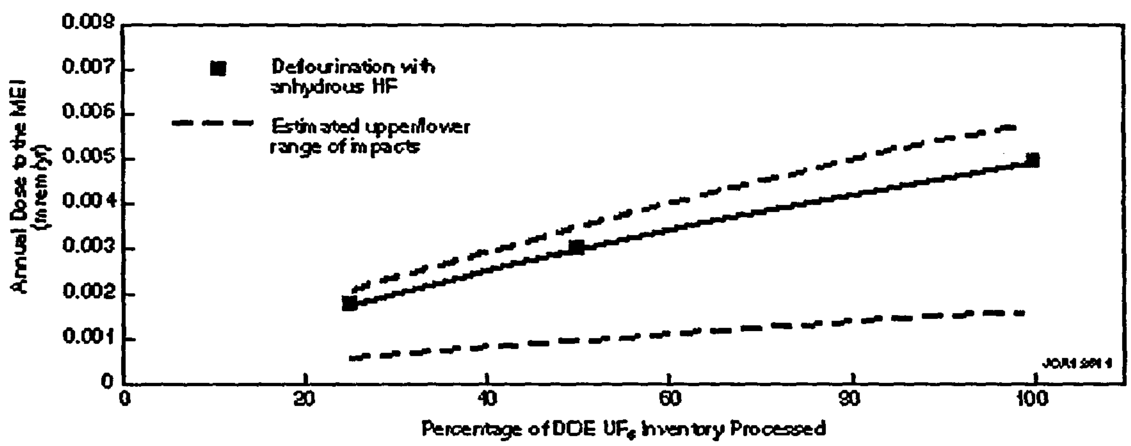

FIGURE K.4 Estimated Annual Dose to the Noninvolved Worker MEI from the Conversion of UF_6 to U_3O_8 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

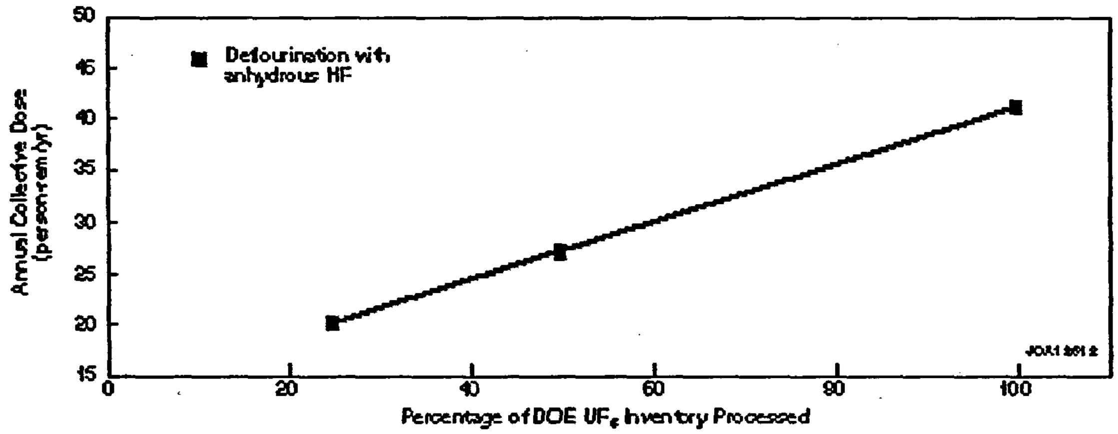

FIGURE K.5 Estimated Annual Collective Dose to Involved Workers from the Conversion of UF_6 to U_3O_8 (No range is presented because the estimated collective doses to involved workers were almost identical between conversion technologies.)

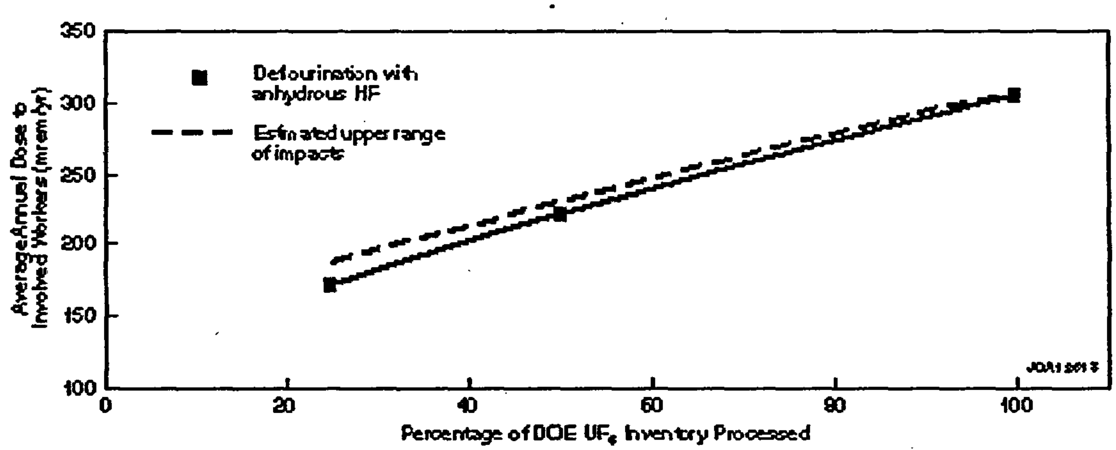

FIGURE K.6 Estimated Annual Average Individual Dose to Involved Workers from the Conversion of UF_6 to U_3O_8 (The upper and lower ranges reflect differences in conversion technologies.)

determined for the 100% case. The area enclosed by the lines in each figure indicates the range of impacts expected for throughputs between 25% and 100%, taking into account both technology and site differences.

The results of the parametric analysis for conversion to U_3O_8 (as shown in Figures K.1 through K.6) indicate that the radiological impacts would scale relatively linearly with the quantity of depleted UF_6 processed annually. The impacts of the 25% and 50% cases would be smaller than those for the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than half of the impacts for the 100% case). The radiation doses to the general public would be greater than those to noninvolved workers because of longer exposure times and, for the collective dose, larger population size. The doses shown in the figures can be converted to the number (or risk) of LCFs by multiplying the doses (in rem or person-rem) by 0.0005 LCF/person-rem for members of the public and 0.0004 LCF/person-rem for workers. Additional discussion of the significance of the estimated doses is provided in Appendix F.

For conversion to UO_2, the estimated radiation doses for the 100%, 50%, and 25% throughput cases are presented in Figures K.7 through K.12 for each of the six receptor scenarios considered in the PEIS. The results are presented in a manner similar to the results discussed previously for conversion to U_3O_8. The general relationship between radiological impacts and throughput for conversion to UO_2 is similar to that for conversion to U_3O_8; that is, the radiological impacts would decrease with decreasing throughput. The estimated radiological impacts (doses and LCFs) from normal operation of a full-scale (100%) facility for converting depleted UF_6 to UO_2 are described in Appendix F, Section F.3.1.1.

For conversion to metal, the estimated radiation doses for the 100%, 50%, and 25% throughput cases are presented in Figures K.13 through K.18 for each of the six receptor scenarios considered in the PEIS. Similar to conversion to U_3O_8 and UO_2, the radiological impacts from conversion to metal would decrease with decreasing throughput. The estimated radiological impacts (doses and LCFs) from the normal operation of a full-scale (100%) facility for converting depleted UF_6 to uranium metal are described in Appendix F, Section F.3.1.1.

The estimated radiological impacts from operation of the cylinder treatment facility are less than the impacts from the operations of the conversion facilities. Low-level exposures would be expected for involved workers and negligible exposures for noninvolved workers and the general public. The estimated radiation doses for the 100%, 50%, and 25% throughput cases are presented in Figures K.19 through K.24 for each of the six receptor scenarios considered in the PEIS.

K.2.1.2 Chemical Impacts

The estimated impacts from chemical exposures during the normal operation of full-scale (100%) facilities for converting depleted UF_6 to U_3O_8, UO_2, and uranium metal are described in Appendix F, Section F.3.1.2. The results of the 100% case analyses indicated that noninvolved

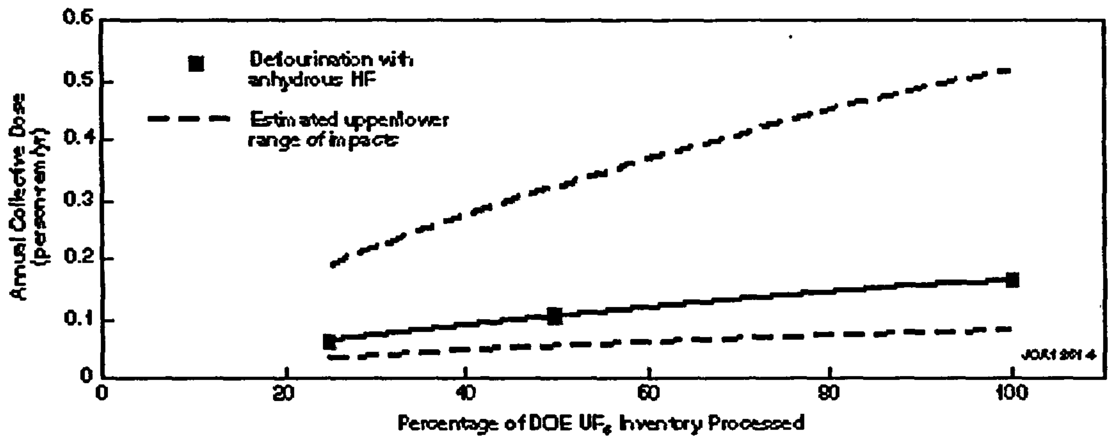

FIGURE K.7 Estimated Annual Collective Dose to Members of the Public from the Conversion of UF_6 to UO_2 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

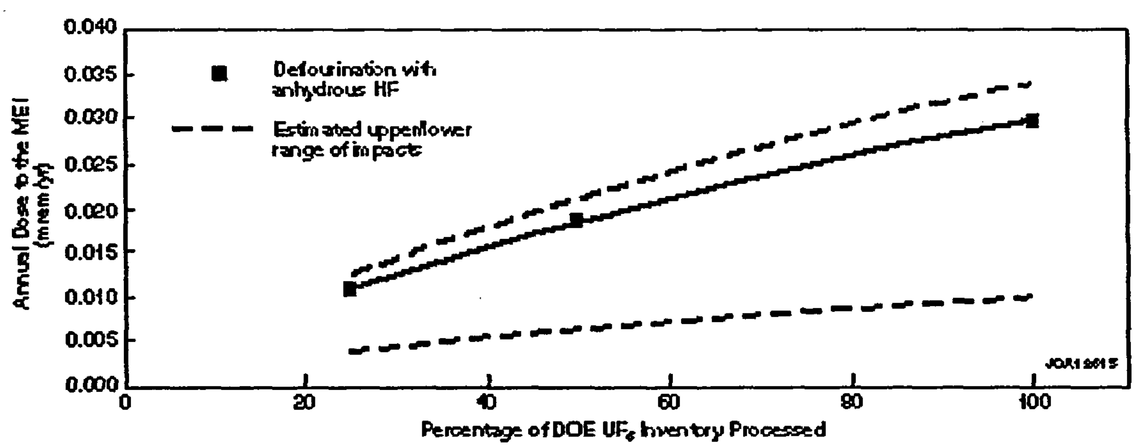

FIGURE K.8 Estimated Annual Dose to the General Public MEI from the Conversion of UF_6 to UO_2 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

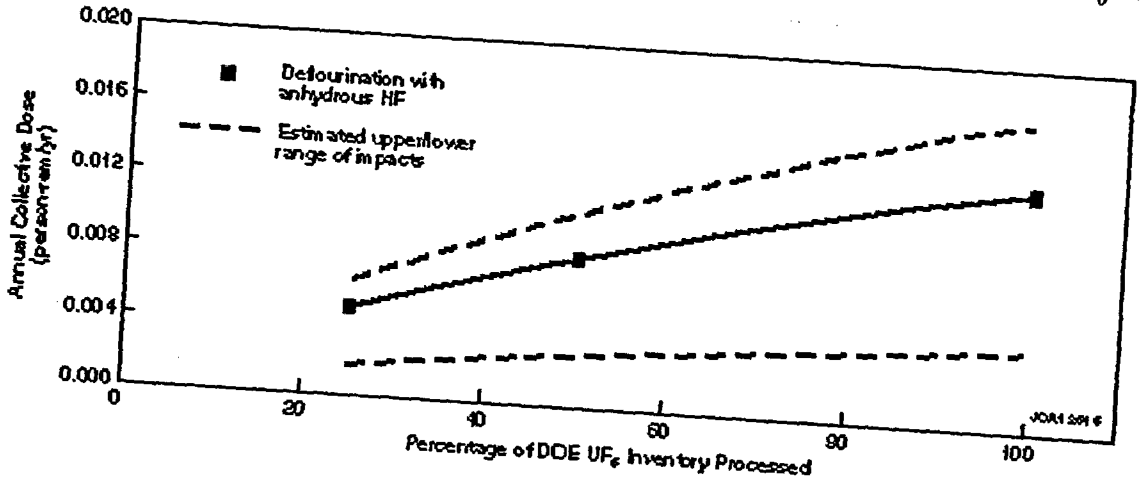

FIGURE K.9 Estimated Annual Collective Dose to Noninvolved Workers from the Conversion of UF_6 to UO_2 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

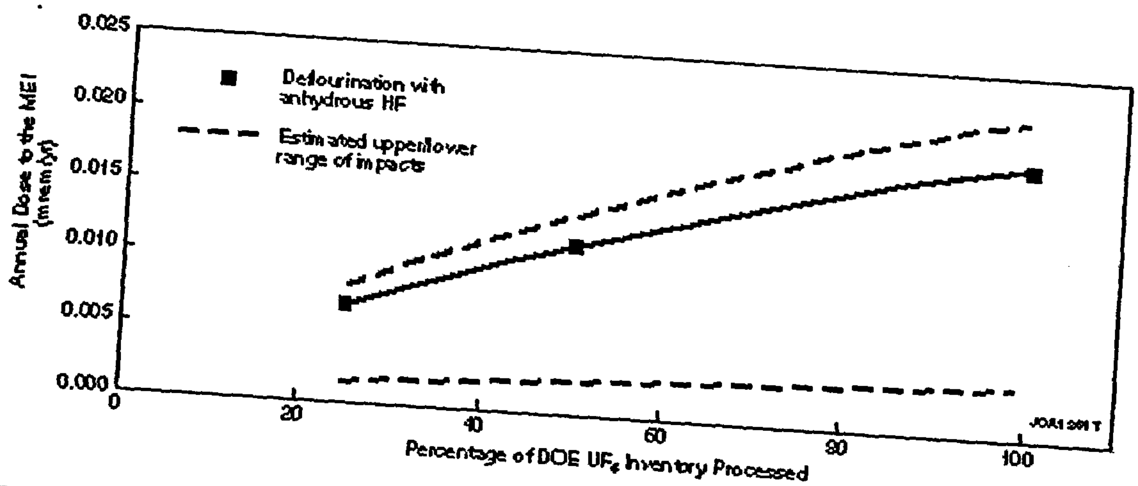

FIGURE K.10 Estimated Annual Dose to the Noninvolved Worker MEI from the Conversion of UF_6 to UO_2 (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

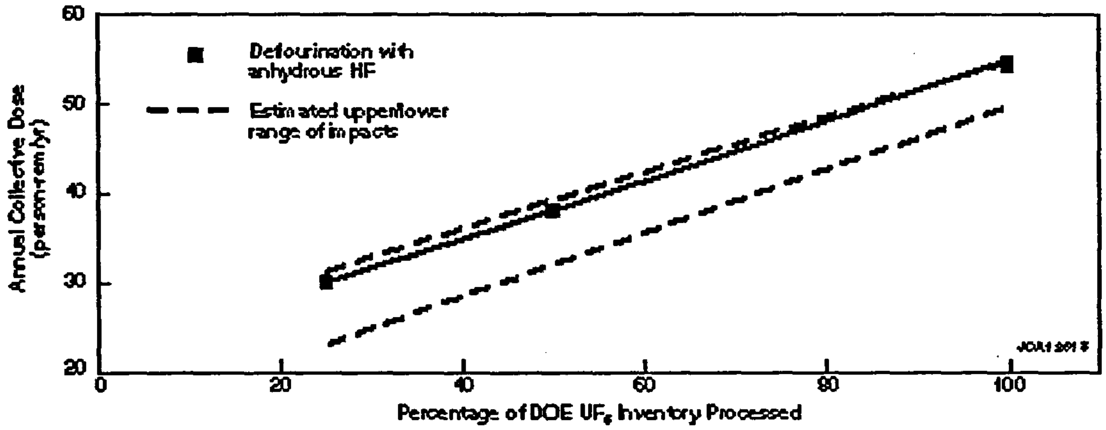

FIGURE K.11 Estimated Annual Collective Dose to Involved Workers from the Conversion of UF_6 to UO_2 (The upper and lower ranges reflect differences in conversion technologies.)

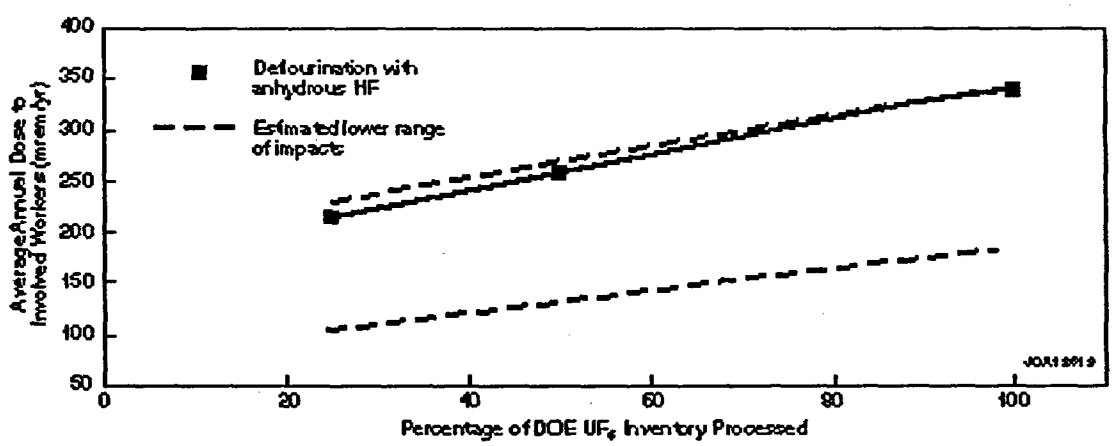

FIGURE K.12 Estimated Annual Average Individual Dose to Involved Workers from the Conversion of UF_6 to UO_2 (The upper and lower ranges reflect differences in conversion technologies.)

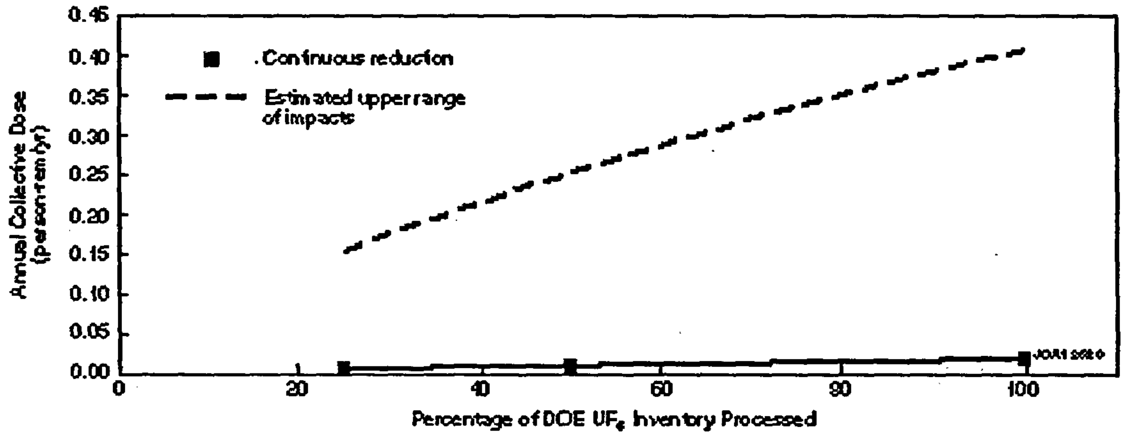

FIGURE K.13 Estimated Annual Collective Dose to Members of the Public from the Conversion of UF_6 to Uranium Metal (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

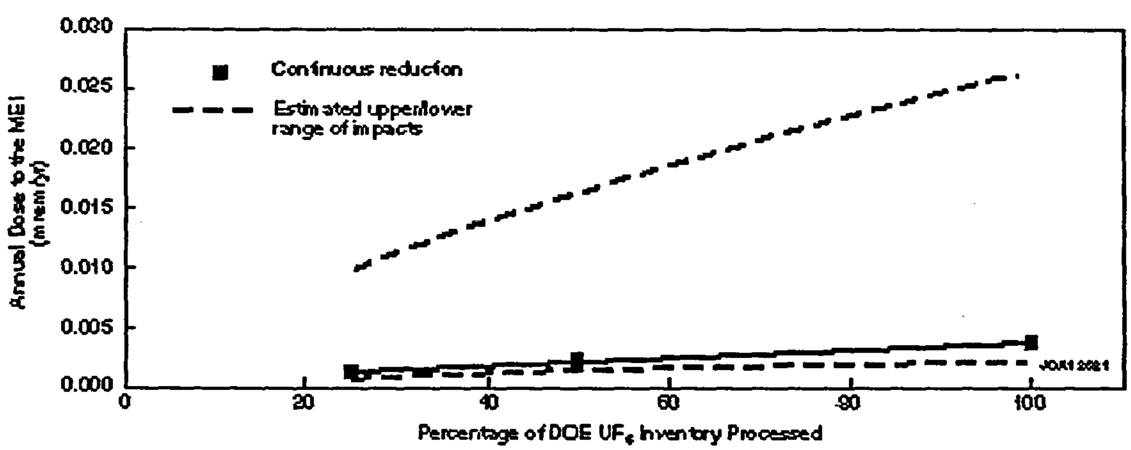

FIGURE K.14 Estimated Annual Dose to the General Public MEI from the Conversion of UF_6 to Uranium Metal (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

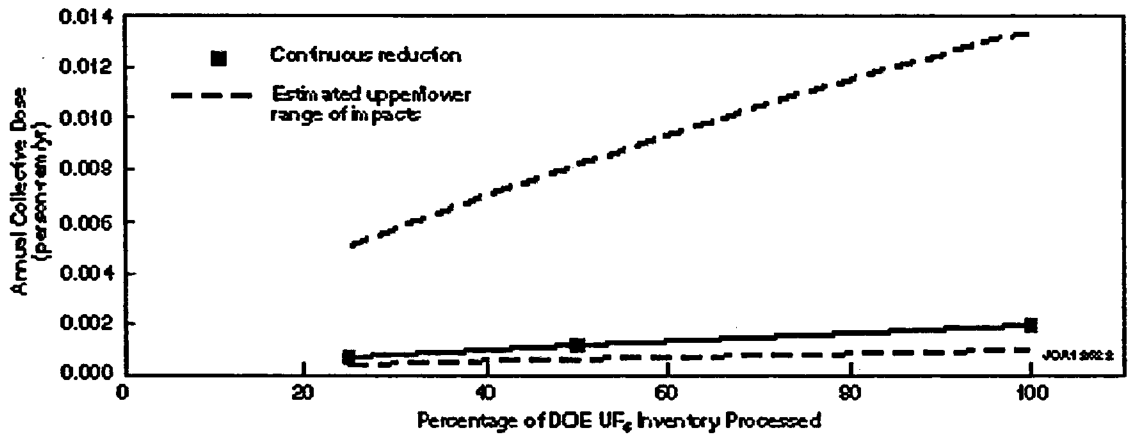

FIGURE K.15 Estimated Annual Collective Dose to Noninvolved Workers from the Conversion of UF_6 to Uranium Metal (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

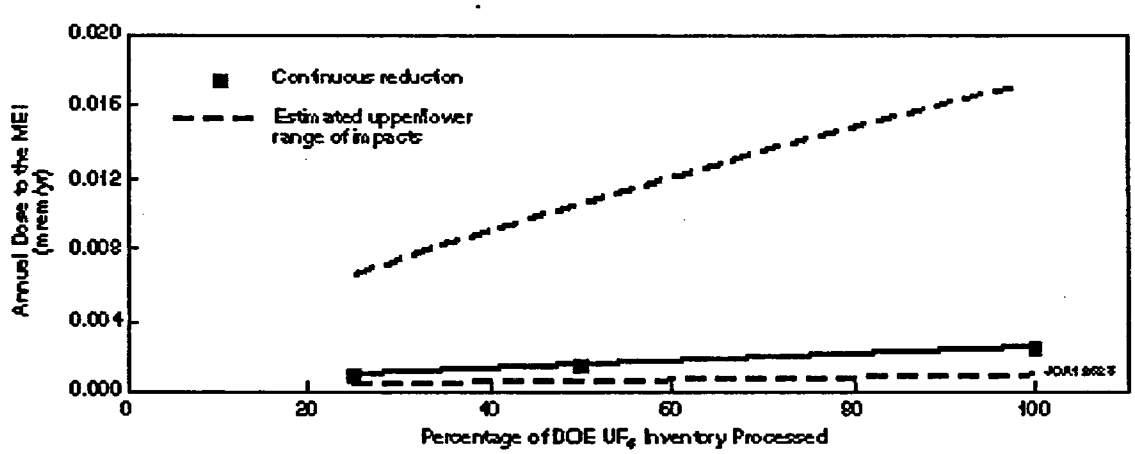

FIGURE K.16 Estimated Annual Dose to the Noninvolved Worker MEI from the Conversion of UF_6 to Uranium Metal (The upper and lower ranges reflect differences in both conversion technologies and representative site characteristics.)

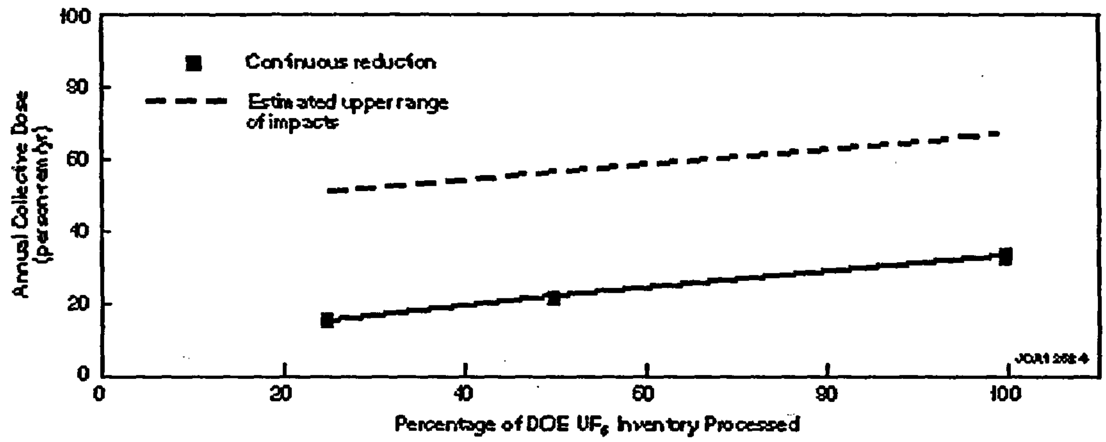

FIGURE K.17 Estimated Annual Collective Dose to Involved Workers from the Conversion of UF_6 to Uranium Metal (The upper and lower ranges reflect differences in conversion technologies.)

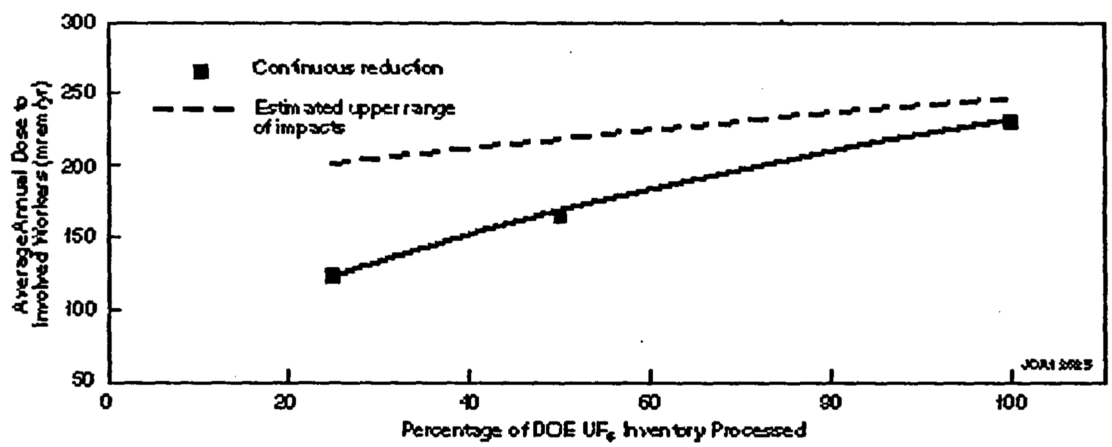

FIGURE K.18 Estimated Annual Average Individual Dose to Involved Workers from the Conversion of UF_6 to Uranium Metal (The upper and lower ranges reflect differences in conversion technologies.)

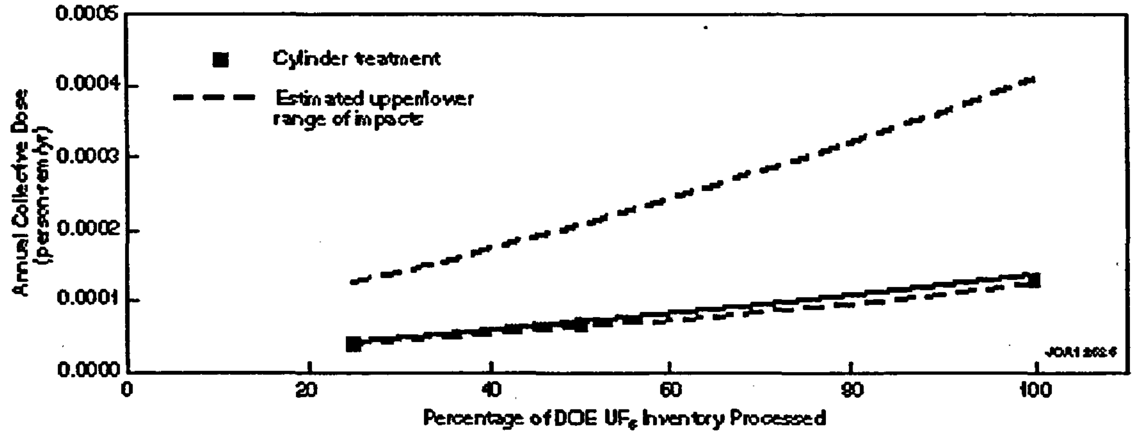

FIGURE K.19 Estimated Annual Collective Dose to Members of the Public from the Cylinder Treatment Facility (The upper and lower ranges reflect differences in representative site characteristics.)

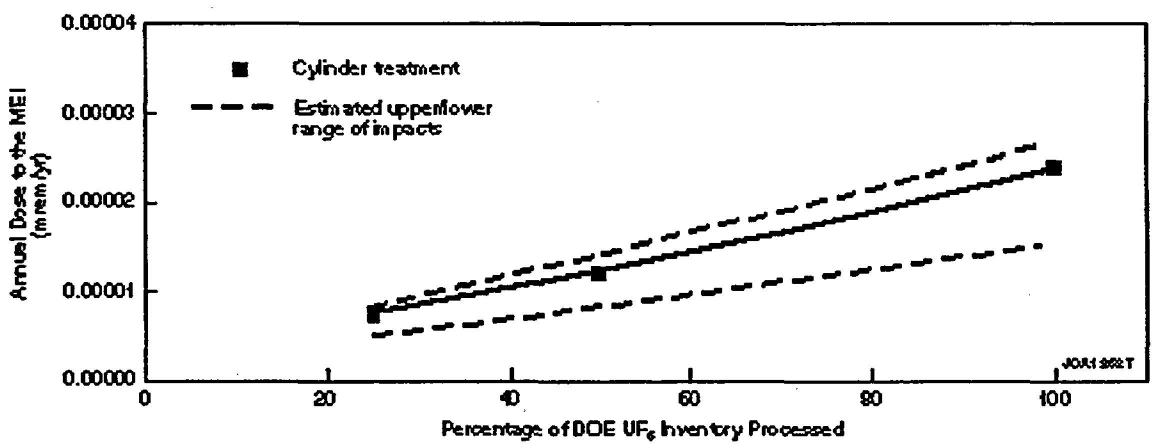

FIGURE K.20 Estimated Annual Dose to the General Public MEI from the Cylinder Treatment Facility (The upper and lower ranges reflect differences in representative site characteristics.)

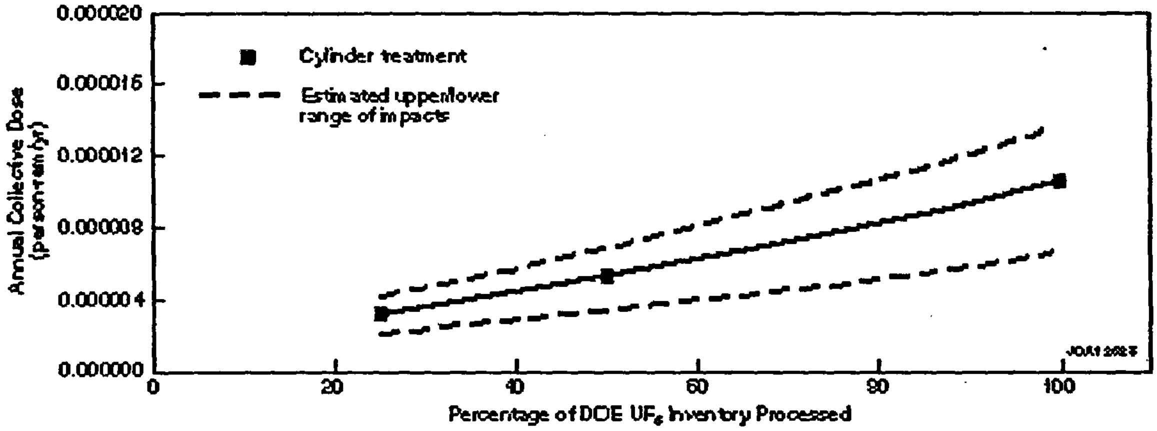

FIGURE K.21 Estimated Annual Collective Dose to Noninvolved Workers from the Cylinder Treatment Facility (The upper and lower ranges reflect differences in representative site characteristics.)

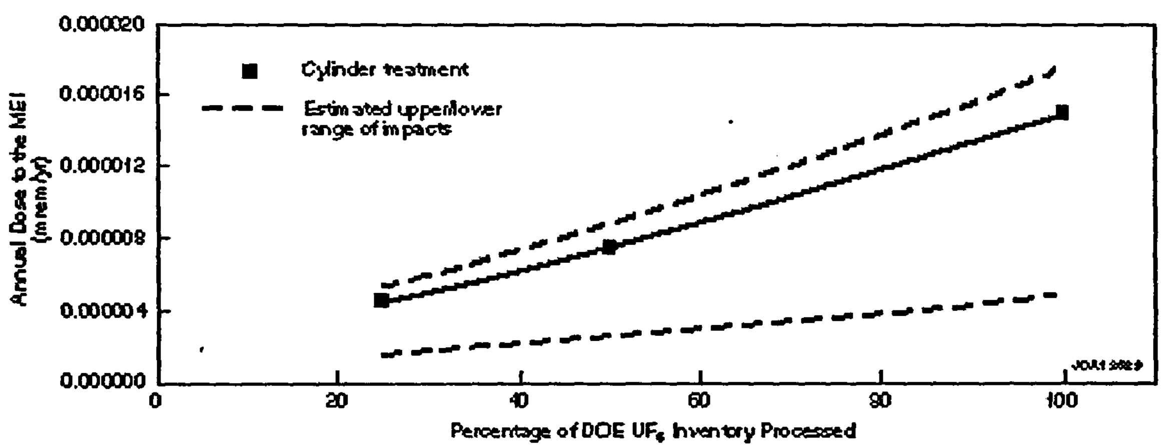

FIGURE K.22 Estimated Annual Dose to the Noninvolved Worker MEI from the Cylinder Treatment Facility (The upper and lower ranges reflect differences in representative site characteristics.)

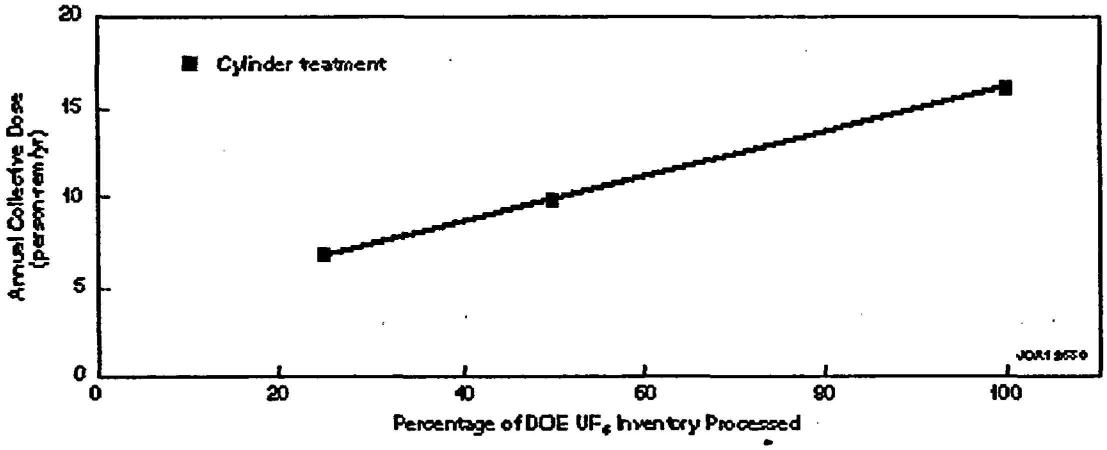

FIGURE K.23 Estimated Annual Collective Dose to Involved Workers from the Cylinder Treatment Facility

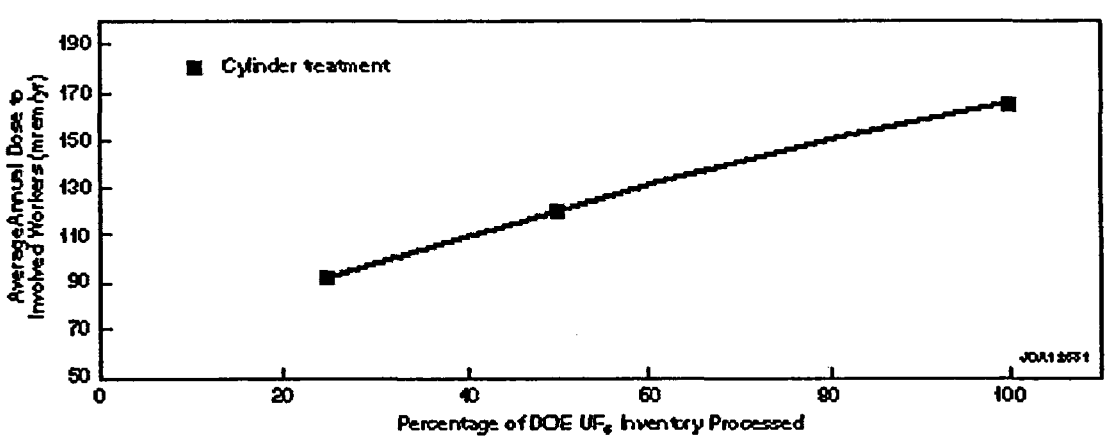

FIGURE K.24 Estimated Annual Average Individual Dose to Involved Workers from the Cylinder Treatment Facility

workers and members of the general public would receive very low exposures to chemicals from operation of the conversion facilities and that no adverse health impacts would be expected. For the 100% cases, the calculated hazard indices were much less than 1 for all three conversion options (a hazard index of greater than 1 indicates the potential for health impacts). For the parametric analysis of the 25% and 50% throughput cases, calculated hazard indices for noninvolved workers and members of the general public were proportionally smaller than those for the 100% cases. Therefore, because the hazard indices are much less than 1, no adverse health impacts from chemical exposures would be expected for throughput rates between 25% and 100%.

The chemical impacts from operations of the cylinder treatment facility were estimated to be less than the impacts from operations of the conversion facilities, therefore resulting in no adverse health impacts to noninvolved workers and the general public for the 25%, 50%, and 100% cases.

K.2.2 Human Health — Accident Conditions

K.2.2.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from potential accidents during operation of the full-scale (100%) conversion facilities are presented in Appendix F, Section F.3.2.1. Analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented only for those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

On the basis of the assessment of the 25% and 50% conversion cases, the radiological accident impacts associated with each of the parametric cases would be the same as those presented for the 100% cases in Appendix F. The impacts would be the same because the bounding accidents within each frequency category (those producing the greatest consequences) would be the same for all cases (100%, 50%, and 25%). The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. Some of the impacts from other accidents considered for the 25% and 50% cases (nonbounding) would be different than those for the 100% cases. In general, the impacts of these nonbounding accidents for the 50% and 25% cases would be less than those for the 100% cases because of the reduced throughput.

All accidents associated with the cylinder treatment facilities discussed in Appendix F would be the same for the parametric analysis (LLNL 1997a). The frequencies of some accidents, such as drum spills, might decrease as the number of drums handled decreased with facility throughput. However, it is not expected that the small changes in frequencies for specific accidents would change the overall frequency category for those accidents. As a result, the accident impacts associated with the cylinder treatment facility would be the same for all parametric cases.

K.2.2.2 Chemical Impacts

The estimated chemical impacts from potential accidents during the operation of full-scale (100%) conversion facilities are presented in Appendix F, Section F.3.2.2. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented only for those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

As for the radiological accident impacts, the chemical accidents producing the greatest consequences for the 25% and 50% parametric cases would be the same as those assessed for the 100% cases in Appendix F. The impacts would be similar because the bounding accidents within most frequency categories would be the same for the 100%, 50%, and 25% cases, and in those cases where the accidents were different, no adverse chemical impacts were estimated. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. Some of the impacts from other accidents considered for the 25% and 50% cases (nonbounding accidents) would be different than those for the 100% cases. In general, the impacts of these other accidents for the 50% and 25% cases would be less than those for the 100% cases because of the reduced throughput.

All accidents associated with the cylinder treatment facilities discussed in Appendix F would be the same for the parametric analysis (LLNL 1997a). The frequencies of some accidents, such as drum spills, might decrease as the number of drums handled decreased with facility throughput. However, it is not expected that the small changes in frequencies for specific accidents would change the overall frequency category for those accidents. As a result, the overall chemical accident impacts associated with cylinder treatment would be the same for all parametric cases.

K.2.2.3 Physical Hazards

The estimated health impacts, such as on-the-job injuries and fatalities, from potential physical accidents during the construction and operation of full-scale (100%) conversion facilities are presented in Appendix F, Section F.3.2.3. The impacts of the 25% and 50% cases would be smaller than those for the 100% cases, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than half of the impacts for the 100% case).

The estimated total fatalities over the entire period of construction and operations for the U_3O_8 conversion options for the 25%, 50%, and 100% cases would be 0.29, 0.32, and 0.35, respectively (both conversion options analyzed resulted in the same fatality estimates). For the UO_2 conversion options, the estimated total fatalities for the 25%, 50%, and 100% cases would range from 0.35 to 0.49, 0.38 to 0.54, and 0.40 to 0.59, respectively. For the metal conversion options, total fatalities for the 25%, 50%, and 100% cases would range from 0.33 to 0.49, 0.36 to 0.52, and 0.4 to 0.55, respectively.

The total numbers of injuries over the entire period of construction and operation of the specific U_3O_8, UO_2, and metal conversion options analyzed parametrically are illustrated by the solid black line in Figures K.25 through K.27. The estimated upper ranges of impacts for all options examined in the PEIS are illustrated by the dotted lines in the figures (because both U_3O_8 options analyzed resulted in the same number of estimated injuries, only one line is shown in Figure K.25). The ranges of predicted injury incidence for the conversion options would be roughly comparable, reflecting the generally similar requirements for constructing and operating the three types of conversion facilities.

The estimated fatalities for the 25%, 50%, and 100% cases of construction and operation of a cylinder treatment facility would be 0.13, 0.16, and 0.19, respectively. The estimated number of injuries over the entire period of construction and operations would range from 122 to 170. The impacts are shown in Figure K.28 for throughputs ranging from 25% to 100%.

K.2.3 Air Quality

The estimated impacts on air quality during construction and operation of full-scale (100%) conversion facilities are presented in detail in Appendix F, Section F.3.3. All of the pollutant concentrations produced by the 100% capacity version of the conversion facilities would be well below their respective air quality standards, with the possible exception of dust emissions during construction. During construction, short-term particulate concentrations were estimated to potentially approach the applicable air quality standards for all options, although the condition would be temporary and minimized by good construction practices. The air quality impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases. During construction, short-term impacts for the parametric cases would be less than those for the 100% cases, and impacts during operations would also be negligible. However, the air quality impacts from operations would not scale proportionally with facility capacities. The impacts from a 25% capacity plant would be from about 45% to 100% of those from the full-capacity plant, depending on the specific source of the emissions.

All of the pollutant concentrations produced by the 100% capacity version of the cylinder treatment facility would be well below the respective air quality standards (see Appendix F, Section F.3.3). The air quality impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

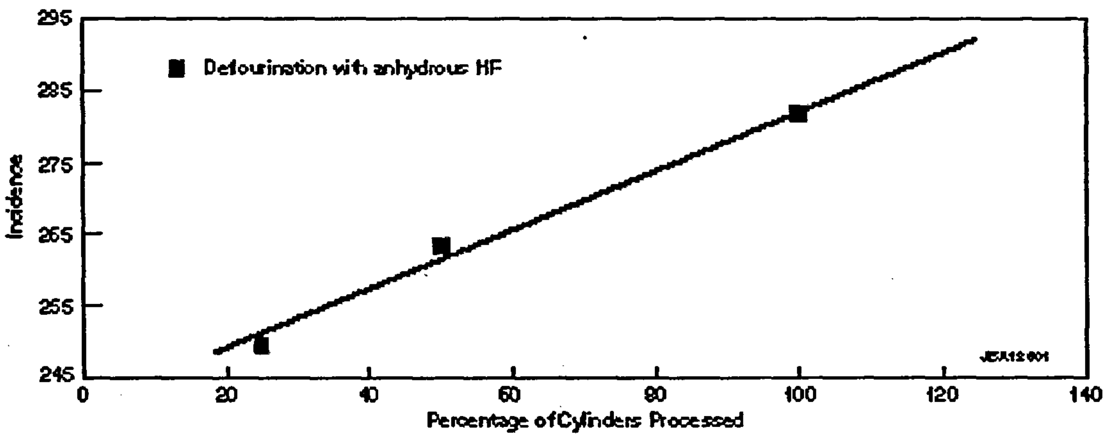

FIGURE K.25 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) for the Conversion of UF_6 to U_3O_8 (No range is presented because the number of injuries would be almost identical between the U_3O_8 conversion technologies.)

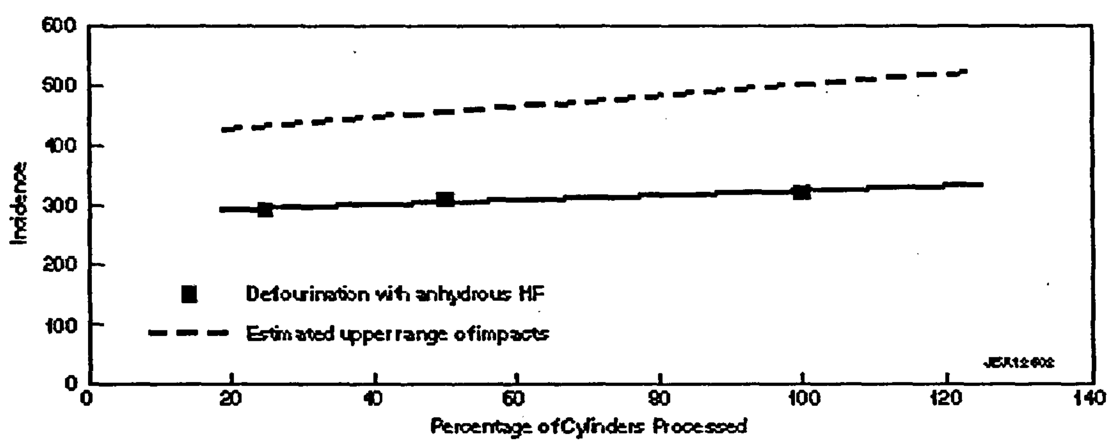

FIGURE K.26 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) for the Conversion of UF_6 to UO_2 (The ranges reflect differences in UO_2 conversion technologies.)

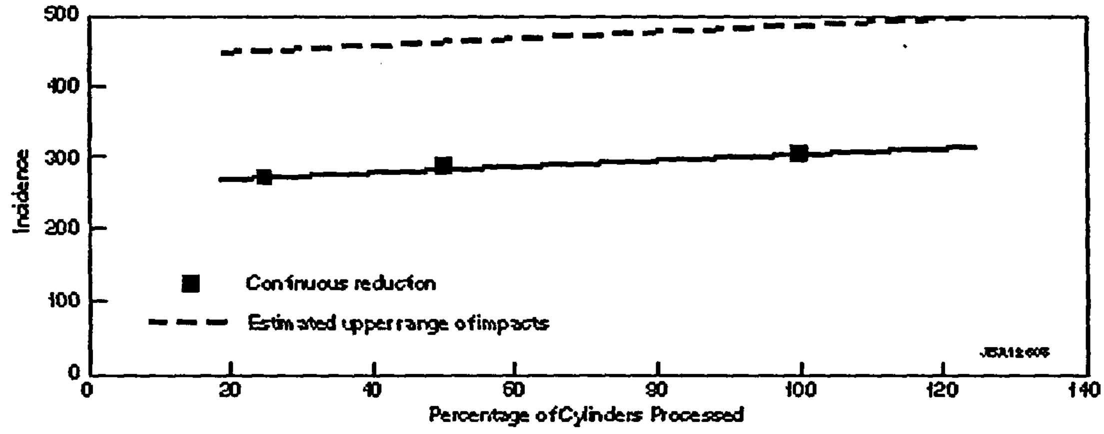

FIGURE K.27 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) for the Conversion of UF_6 to Uranium Metal (The ranges reflect differences in uranium metal conversion technologies.)

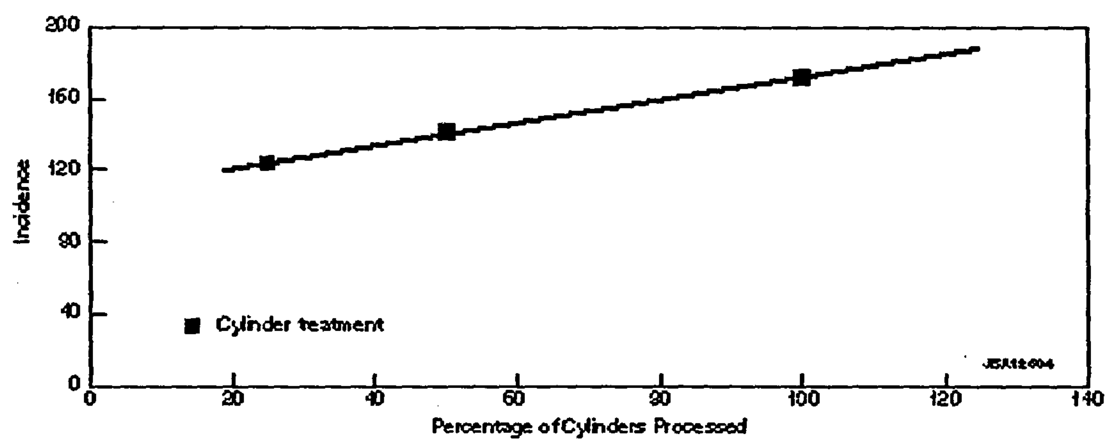

FIGURE K.28 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) for the Cylinder Treatment Facility

K.2.4 Water and Soil

K.2.4.1 Surface Water

The estimated impacts on surface water during construction, operation, and potential accidents for full-scale (100%) conversion facilities and the cylinder treatment facility are presented in detail in Appendix F, Section F.3.4.1. The potential impacts evaluated included changes in runoff, changes in quality, and floodplain encroachment. The impacts to surface water from the 100% cases were found to be negligible for all three conversion options. The impacts to surface water estimated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.2.4.2 Groundwater

The estimated impacts on groundwater during construction, operation, and potential accidents for full-scale (100%) conversion facilities and the cylinder treatment facility are presented in detail in Appendix F, Section F.3.4.2. The potential impacts evaluated included changes in the depth to groundwater, the direction of groundwater flow, recharge, and quality. The impacts to groundwater from the 100% cases were found to be negligible for all three conversion options. The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.2.4.3 Soil

The estimated impacts to soil during construction, operation, and potential accidents for full-scale (100%) conversion facilities and the cylinder treatment facility are presented in detail in Appendix F, Section F.3.4.3. The potential impacts evaluated included changes in topography, permeability, quality, and erosion potential. The impacts to soil from the 100% cases were found to be negligible for all three conversion options. The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.2.5 Socioeconomics

The socioeconomic impacts of U_3O_8, UO_2, and metal conversion and cylinder treatment facilities for the 50% and 25% parametric cases would be less than the impacts of the base-case facility sizes. Cost information was not available in sufficient detail to allow an analysis of impacts using the same methodology that was used for the base cases. The impacts of parametric cases were therefore assessed qualitatively, based on the assumption that changes in the cost of equipment, materials, and labor between cases would be proportional to changes in total life-cycle cost. Compared with base-case facility sizes, smaller conversion and cylinder treatment facilities would result in the following: less direct and indirect employment and income would be created in the region of influence (ROI) at each representative site; fewer people would migrate into the ROI with fewer total jobs created, meaning fewer rental and owner-occupied houses would be needed; and the impact on local jurisdictional revenues and expenditures would be smaller.

K.2.6 Ecology

Site preparation for the construction of conversion and cylinder treatment facilities would result in the disturbance of biotic communities, including the permanent replacement of habitat with structures, paved areas, and landscaping (see Section K.2.9). Existing vegetation would be destroyed during land-clearing activities. Wildlife would be disturbed by land clearing, noise, and human presence.

Normal operations of the conversion facility would generate minor atmospheric emissions of criteria pollutants, HF, and uranium compounds. However, resulting air concentrations would be expected to be negligible under all three cases analyzed, resulting in negligible impacts to ecological resources.

Effluent discharges to surface water would contain low levels of contaminants, including uranium. However, under all three cases, contaminant concentrations in the undiluted effluent would be below levels that adversely affect aquatic biota.

Depending on the exact location of the conversion facility, the loss of approximately 10 to 30 acres (4 to 12 ha) of undeveloped land and habitat, representing the rounded 25-100% capacity range for oxide and metal conversion facilities, might constitute a minor to moderate adverse impact to vegetation and wildlife. For the cylinder treatment facility, the loss of 6.8 to 8.7 acres (2.8 to 3.5 ha) of undeveloped land and the permanent loss of 3.2 to 4.5 acres (1.3 to 1.8 ha) of habitat would constitute a negligible to low adverse impact. (See Section K.2.9 for details on land use assumptions.) When these facilities would be sited, all appropriate measures would be taken to preclude or minimize such impacts.

Impacts to wetlands and state and federally protected species due to facility construction would depend on facility location. Avoidance of wetland areas would be included during facility planning. Impacts to air quality, surface water, groundwater, and soil during construction and operations would be expected to be negligible, as would the resulting derived impacts to ecological resources.

K.2.7 Waste Management

The estimated impacts from waste management operations for construction and operation of full-scale (100%) conversion facilities are presented in detail in Appendix F, Section F.3.7. Potential moderate impacts to site, regional, and national waste management operations were found for all 100% throughput conversion option cases. On the basis of information provided in the engineering analysis report (LLNL 1997a), the impacts resulting from construction and operation of the conversion facility for the 25% and 50% parametric cases would be roughly linear for throughput ranges of between 25% and 100%. Minimal waste management impacts would result from construction-generated wastes. The annual amounts of waste generated during facility operations are shown in Table K.2. Overall, the waste input resulting from normal operations at the conversion facilities would have a low to moderate impact on waste management capacities locally or across the DOE complex.

There is a significant possibility that the magnesium fluoride (MgF_2) waste generated in the conversion to metal option would be sufficiently contaminated with uranium to require disposal as low-level radioactive waste (LLW) rather than as solid nonhazardous waste. Such disposal might require the MgF_2 waste to be grouted, generating up to 12,300 m^3/yr of grouted waste for LLW disposal. This volume represents a low (5.8%) impact to the DOE complexwide LLW disposal capacity for the 100% throughput case (scales linearly for the three throughput cases).

K.2.8 Resource Requirements

The estimated impacts from resource requirements during construction and operation of full-scale (100%) conversion facilities are presented in detail in Appendix F, Section F.3.8. The impacts on resources would be expected to be small for the 100% capacity conversion case. Although the resource requirements for the two conversion parametric analyses would be less than the 100% case, the reduction in requirements would not be linearly proportional to the decrease in throughput. For example, the amount of material required to construct a conversion facility for the 25% throughput case would be only about 10% to 20% less than the amount required for the 100% throughput facility due to "economies-of-scale."

Construction and operation of the proposed conversion options would consume irretrievable amounts of electricity, fuel, concrete, steel and other metals, water, and miscellaneous chemicals. The total quantities of commonly used materials would not be expected to be significant. No strategic and critical materials (e.g., Monel or Inconel) in significant quantities are projected to be consumed during construction or operation. The conversion options are not considered resource-intensive, and the resources required are generally not considered rare or unique. Furthermore, committing any of these resources would not be expected to cause a negative impact on the availability of these resources within local areas or nationally for the 100%, 50%, and 25% cases.

TABLE K.2 Waste Generation from Conversion Facilities for 100%, 50%, and 25% Throughput Cases

	Waste Generated (m^3/yr) by Conversion to U_3O_8, UO_2, or Uranium Metal for Three Throughput Cases								
	U_3O_8			UO_2			Uranium Metal		
Waste Category	100%	50%	25%	100%	50%	25%	100%	50%	25%
Low-level radioactive waste									
Combustible	77	73	70	88	84	82	77	71	69
Noncombustible	62	45	33	82	63	45	112	88	69
Grouted	466	233	116	466	233	116	37	26	18
Low-level mixed waste	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Hazardous waste	7.3	6.7	6.1	7.3	6.7	6.1	7.3	6.7	6.1
Nonhazardous waste									
Solids	535	512	490	612	585	566	6,680[a]	3,590[a]	2,040[a]
Wastewater	58,000	36,300	24,600	74,900	47,300	31,000	96,500	57,500	37,500
Sanitary waste	4,920	4,730	4,540	5,680	5,380	5,220	5,300	4,950	4,800

[a] Includes the following volumes of MgF_2 waste: 6,120 m^3/yr for the 100% case; 3,060 m^3/yr for the 50% case, and 1,530 m^3/yr for the 25% case.

Construction and operation of a cylinder treatment facility would also consume irretrievable amounts of electricity, fuel, concrete, steel, water, and miscellaneous gases and chemicals. Similar to the conversion facilities, the cylinder treatment facility option would not be expected to result in negative impacts relative to its resource requirements.

K.2.9 Land Use

K.2.9.1 Conversion to U_3O_8

Potential impacts to land use from the construction and operation of a U_3O_8 conversion facility would include the acquisition and clearing of required land, minor and temporary disruptions to contiguous land parcels, and increases in vehicular traffic. Site preparation for the construction of a facility to convert 25%, 50%, and 100% of the depleted UF_6 inventory to U_3O_8 by defluorination with anhydrous HF would require the disturbance of approximately 14, 16, and 20 acres (5.5, 6.4, and 8.1 ha), respectively. Within this disturbed area, the facility would require the permanent replacement of approximately 9, 11, and 13 acres (3.6, 4.2, and 5.3 ha) with structures, paved areas, and landscaping. The amount of land required for the other U_3O_8 conversion technologies would be roughly similar. Even the highest areal requirement would not be great enough to generate other than negligible, temporary disturbance impacts, particularly if the facility was sited in a location already dedicated to similar use with immediate access to infrastructure and utility support.

Impacts to land use outside the boundaries of a U_3O_8 conversion facility at 25%, 50%, or 100% of throughput would be limited to negligible, temporary traffic impacts associated with project construction.

K.2.9.2 Conversion to UO_2

Impacts to land use from the construction and operation of a UO_2 conversion facility, regardless of throughput capacity case, would be negligible and limited to minor and temporary disruptions to contiguous land parcels and increases in vehicular traffic associated with construction activities. Site preparation for the construction of a facility to convert 25%, 50%, and 100% of the depleted UF_6 inventory to UO_2 by the dry process with anhydrous HF would require the disturbance of approximately 16, 19, and 24 acres (6.4, 7.9, and 9.7 ha), respectively. Within this disturbed area, the facility would require the permanent replacement of approximately 10, 13, and 15 acres (4.0, 5.2, and 5.9 ha) with structures, paved areas, and landscaping. The amount of land required for the other UO_2 conversion technologies would be roughly similar, except for gelation, which would require a slightly greater amount of land. Even the highest areal requirement would not be great enough to generate other than negligible, temporary disturbance impacts associated with construction.

Impacts to land use outside the boundaries of a UO_2 conversion facility at 25%, 50%, or 100% of throughput would be limited to minor, temporary traffic impacts associated with project construction.

K.2.9.3 Conversion to Uranium Metal

Impacts to land use from the construction and operation of a facility for uranium metal conversion, regardless of throughput capacity case, would be negligible and limited to minor and temporary disruptions to contiguous land parcels and increases in vehicular traffic associated with construction activities. Site preparation for the construction of a facility to convert 25%, 50%, and 100% of the depleted UF_6 inventory to uranium metal by the continuous metallothermic production technology would require the disturbance of approximately 17, 21, and 26 acres (6.8, 8.6, and 10.6 ha), respectively. Within this disturbed area, the facility would require the permanent replacement of approximately 12, 14, and 15 acres (4.8, 5.5, and 6.2 ha) with structures, paved areas, and landscaping. The amount of land required for the other uranium metal conversion technology would be roughly similar. Even the highest areal requirement would not be great enough to generate other than negligible, temporary disturbance impacts associated with construction.

Impacts to land use outside the boundaries of a conversion-to-metal facility at 25%, 50%, or 100% of throughput would be limited to minor, temporary traffic impacts associated with project construction.

K.2.9.4 Cylinder Treatment Facility

Other than negligible and temporary disruptions to contiguous land parcels, and slight increases in vehicular traffic, virtually no impacts would be expected from a cylinder treatment facility at 25%, 50%, or 100% of throughput capacity. Site preparation for construction of a stand-alone cylinder treatment facility for 25%, 50%, and 100% of the depleted UF_6 inventory would require the disturbance of approximately 6.8, 7.5, and 8.7 acres (2.8, 3.0, and 3.5 ha), respectively. Within this disturbed area, the facility would require the permanent replacement of approximately 3.2, 3.7, and 4.5 acres (1.3, 1.5, and 1.8 ha) with structures and paved areas.

Potential impacts to land use outside the boundaries of a site containing a cylinder treatment facility at 25%, 50%, or 100% of throughput capacity would be limited to negligible, temporary traffic impacts associated with project construction.

K.2.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts could potentially occur if the conversion options considered in this PEIS were implemented — including impacts to cultural resources and environmental justice, as well as to aesthetics (e.g., visual environment), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of conversion facilities. These impacts, although considered, were not analyzed in detail for one or both of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier *National Environmental Policy Act* (NEPA) documentation when specific sites are considered.

- Consideration of the impacts would not contribute to differentiation among the alternatives; therefore, it would not affect the decisions to be made in the Record of Decision that will be issued following publication of this PEIS.

K.3 LONG-TERM STORAGE OPTIONS

The parametric analysis of the long-term storage options considered the environmental impacts of storing 25% and 50% of the depleted UF_6 inventory as UF_6 or as an oxide form. In both cases, it was assumed that the uranium material would be actively placed into storage over a 20-year period (from 2009 through 2028), and then stored for an additional 11-year period (from 2029 through 2039) with only routine monitoring and maintenance. The assessment considered the environmental impacts that would occur during (1) construction of a storage facility, (2) routine operations, and (3) potential storage facility accidents. The areas of impact and the methodologies used to evaluate the parametric cases were the same as those used to evaluate the 100% cases discussed in detail in Appendix G. The supporting engineering data for the 25% and 50% parametric storage cases are provided in the engineering analysis report (LLNL 1997a).

The environmental impacts for the 100% case are presented in Appendix G for (1) storage as UF_6 in yards, buildings, and an underground mine; (2) storage as U_3O_8 in buildings, vaults, and a mine; and (3) storage as UO_2 in buildings, vaults, and a mine. For the purposes of the parametric analysis, storage as UF_6 in buildings and storage as UO_2 in buildings were considered in detail. These options were chosen to simplify the parametric analysis because all options were evaluated in detail for the 100% base case. The relationships between the options that were identified for the 100% case were used to infer the impacts for all of the long-term storage options for the parametric analysis.

K.3.1 Human Health — Normal Operations

K.3.1.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from the normal operation of full-scale (100%) storage facilities for depleted UF_6 cylinders, UO_2 drums, and U_3O_8 drums are described in Appendix G, Section G.3.1.1. Similar impacts were calculated for the 50% and 25% storage facilities for the parametric analysis. Radiological impacts from the storage as UF_6, UO_2, and U_3O_8 would be limited to involved workers because emissions of uranium to the air and water would be expected to be negligible during normal operations. The radiological impacts for involved workers for the 100%, 50%, and 25% cases are shown in Figures K.29 through K.34. The range of impacts resulting from technology differences (i.e., differences between building, vault, and mine storage facilities) are represented by dashed lines in the figures. The results for the two parametric cases for storage in buildings are shown in the figures as solid points, with a curve drawn between the points to indicate how the impacts would vary as a function of the percent of depleted UF_6 processed. The upper and lower bounds of impacts for the 25% and 50% cases were estimated on the basis of the range determined for the different technologies for the 100% case. The area enclosed by the lines in the figures indicates the range of impacts expected for throughputs between 25% and 100%.

The results of the parametric analysis (as shown in Figures K.29 and K.34) indicate that the collective radiological impacts would scale relatively linearly with the total quantity of depleted UF_6 processed. The impacts of the 25% and 50% cases would be smaller than those for the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than half of the impacts for the 100% case). The doses shown in the figures can be converted to the number (or risk) of LCFs by multiplying the doses (in rem or person-rem) by 0.0004 LCF/person-rem for workers. Additional discussion of the significance of the estimated doses is provided in Appendix G, Section G.3.1.1.

K.3.1.2 Chemical Impacts

The estimated impacts from chemical exposures during the normal operation of full-scale (100%) storage facilities are described in Appendix G, Section G.3.1.2. The results of the 100% case analyses indicated that noninvolved workers and members of the general public would receive very low exposures to chemicals from operation of all storage facilities and that no adverse health impacts would be expected. For the 100% cases, the calculated hazard indices were much less than 1 for all long-term storage options (a hazard index of greater than 1 indicates the potential for health impacts). For the parametric analysis of the 25% and 50% throughput cases, airborne emissions of depleted uranium and HF during normal operations would be less than the 100% cases and extremely small (LLNL 1997a). Therefore, by comparison with the

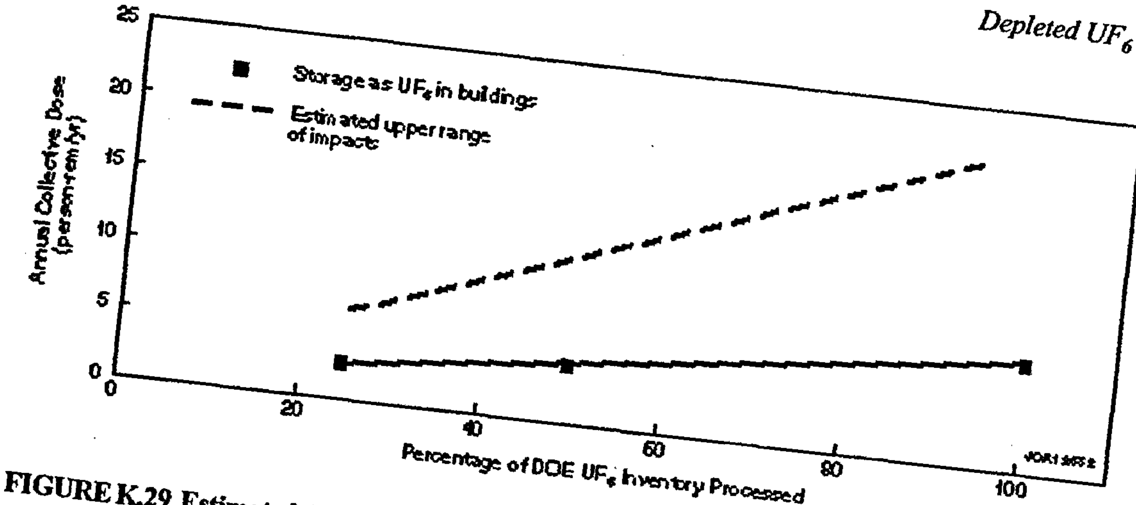

FIGURE K.29 Estimated Annual Collective Dose to Involved Workers from Storage as UF_6 (The upper and lower ranges reflect differences in storage technologies, i.e., buildings, yards, and mine.)

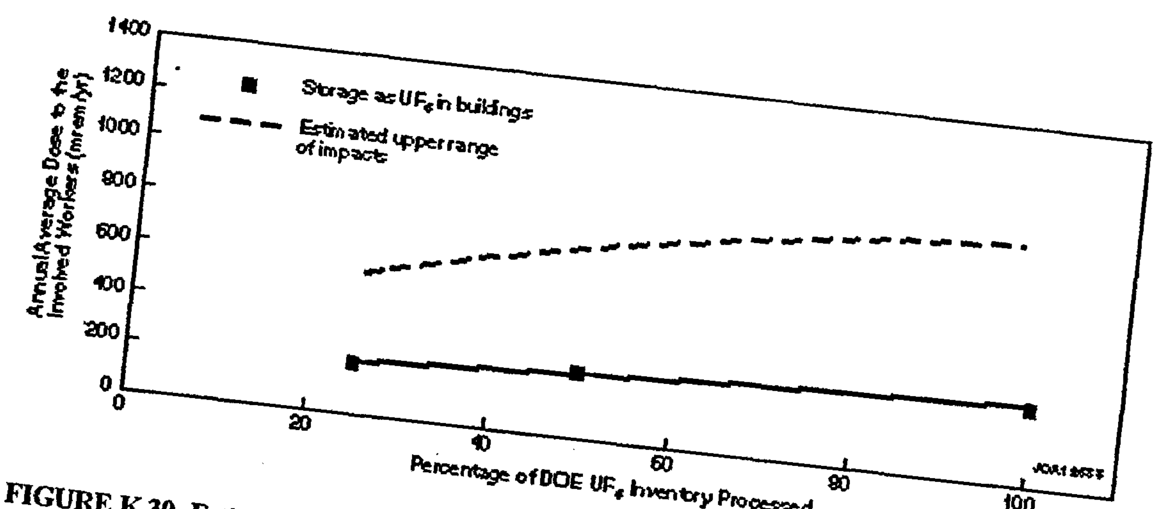

FIGURE K.30 Estimated Annual Average Individual Dose to Involved Workers from Storage as UF_6 (The upper and lower ranges reflect differences in storage technologies, i.e., buildings, yards, and mine.)

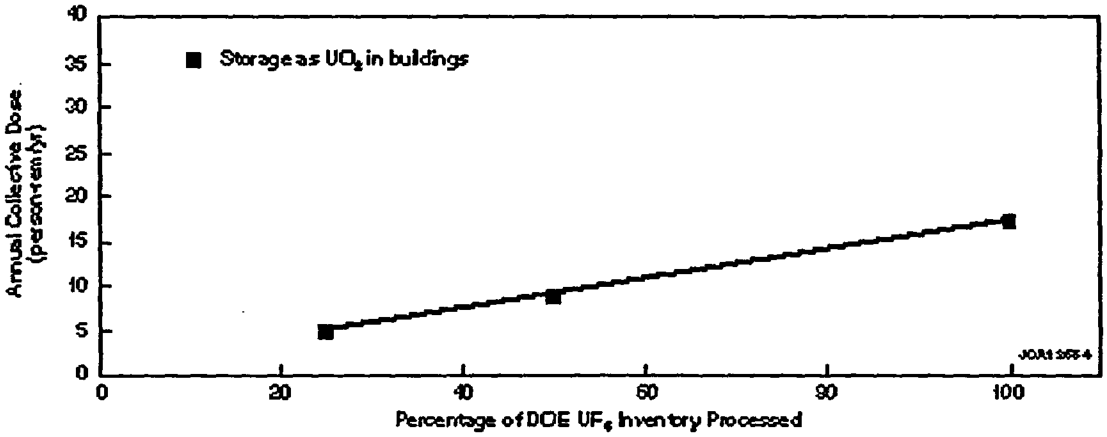

FIGURE K.31 Estimated Annual Collective Dose to Involved Workers from Storage as UO_2 (The collective doses for the different storage technologies would be essentially the same.)

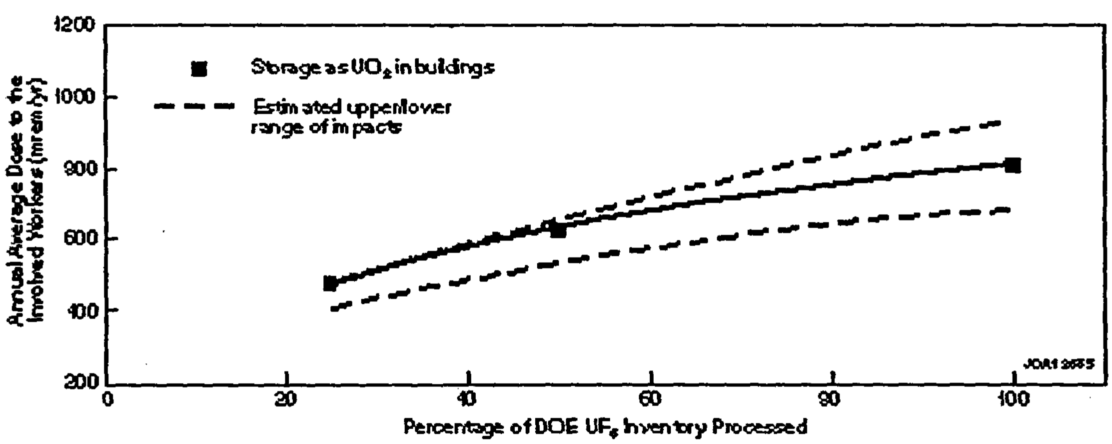

FIGURE K.32 Estimated Annual Average Individual Dose to Involved Workers from Storage as UO_2 (The upper and lower ranges reflect differences in storage technologies, i.e., buildings, vaults, and mine.)

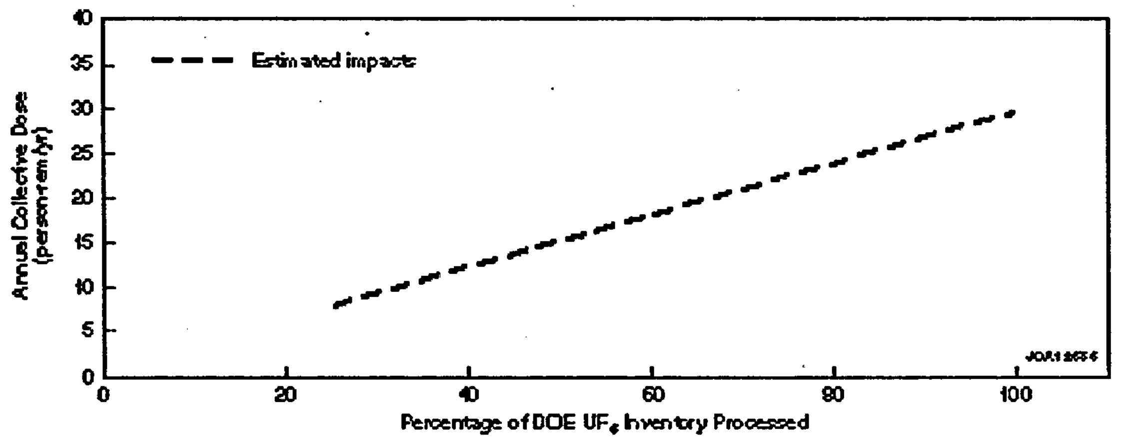

FIGURE K.33 Estimated Annual Collective Dose to Involved Workers from Storage as U_3O_8

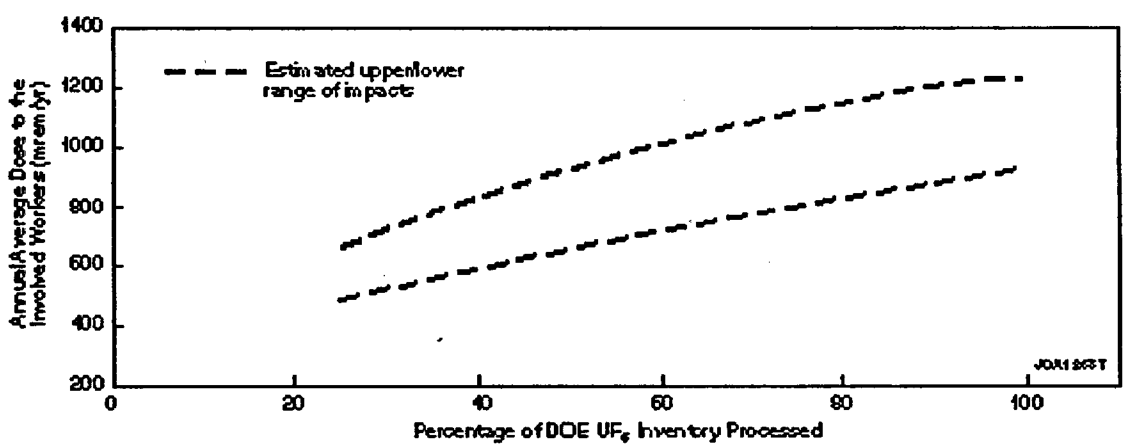

FIGURE K.34 Estimated Annual Average Individual Dose to Involved Workers from Storage as U_3O_8 (The upper and lower ranges reflect differences in storage technologies, i.e., buildings, vaults, and mine.)

100% case results, no adverse health impacts from chemical exposures would be expected for throughput rates between 25% and 100% for all long-term storage options.

K.3.2 Human Health — Accident Conditions

K.3.2.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from potential accidents during the operation of full-scale (100%) storage facilities for depleted UF_6, U_3O_8, and UO_2 are presented in Appendix G, Section G.3.2.1. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented for only those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

Based on the assessment of the 25% and 50% long-term storage cases, the radiological accident impacts associated with each of the parametric cases would be the same as those presented for the 100% case in Appendix G, Section G.3.2.1. The impacts would be identical because the bounding accidents within each frequency category would be the same for the 100%, 50%, and 25% cases. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. However, as a result of the reduced throughput rates, the actual frequencies of some accidents that were related to handling operations (i.e., the "mishandle/drop of drum" accident) would decrease as the number of containers handled decreased. The resulting risk of these accidents would also decrease as their frequencies decreased. However, none of the accident frequencies would change enough to cause the accident to be considered in a different frequency category. Therefore, the overall impacts associated with the long-term storage options would be the same for all parametric cases.

K.3.2.2 Chemical Impacts

The estimated chemical impacts from potential accidents during the operation of full-scale (100%) storage facilities for UF_6 and oxide are presented in Appendix G, Section G.3.2.2. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented for only those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

Based on the assessment of the 25% and 50% long-term storage cases, the chemical accident impacts associated with each of the parametric cases would be the same as those presented for the 100% case in Appendix G, Section G.3.2.2. As for radiological accidents, the impacts would be the same because the bounding accidents within each frequency category would be the same for the 100%, 50%, and 25% cases. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. However, as a result of the reduced throughput rates, the actual frequencies of some accidents related to handling operations (i.e., the "mishandle/drop of drum" accident) would decrease as the number of containers handled decreased. The resulting risk of these accidents would also decrease as their frequencies decreased. However, none of the accident frequencies would change enough to cause the accident to be considered in a different frequency category. Therefore, the overall impacts associated with the long-term storage options would be the same for all parametric cases.

K.3.2.3 Physical Hazards

The estimated health impacts, such as on-the-job injuries and fatalities, from potential physical accidents during the construction and operation of full-scale (100%) storage facilities are presented in Appendix G, Section G.3.2.3. For the 100% storage cases, worker fatalities ranged from about 0.10 to 0.36 for storage as UF_6, 0.16 to 0.24 for storage as UO_2, and 0.29 to 0.43 for storage as U_3O_8 (see Table G.11 in Section G.3.2.3). On-the-job worker injuries for the 100% cases ranged from about 90 to 190 for storage as UF_6, from 150 to 220 for storage as U_3O_8, and from 100 to 140 for storage as UO_2. For the two options analyzed in detail in the parametric analysis, the impacts of the 25% and 50% cases would be smaller than those for the 100% cases, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than 50% of the impacts for the 100% case).

For parametric cases, the number of on-the-job worker fatalities for storage as UF_6 would range from 0.05 to 0.23 at 25% capacity and from about 0.10 to 0.29 at 50% capacity. For storage as UO_2, fatalities would range from 0.07 to 0.15 at 25% capacity and from about 0.10 to 0.19 at 50% capacity. The number of on-the-job worker injuries for storage as UF_6 would range from about 50 to 125 at 25% capacity and from about 60 to 150 at 50% capacity. For storage as UO_2, injuries would range from about 50 to 90 at 25% capacity and from about 75 to 110 at 50% capacity. The predicted number of injuries for UF_6 and UO_2 are shown as a function of throughput in Figures K.35 and K.36, respectively.

Although parametric cases for the U_3O_8 storage options were not explicitly analyzed, if it is assumed that the relative difference in magnitude of impacts for U_3O_8 and UO_2 is similar to that for the 100% cases, then the number of on-the-job fatalities for storage as U_3O_8 would range from about 0.12 to 0.26 for 25% capacity and from about 0.19 to 0.36 at 50% capacity. Estimated injuries for parametric cases of storage as U_3O_8 would range from about 75 to 135 for 25% capacity and from about 113 to 176 for 50% capacity.

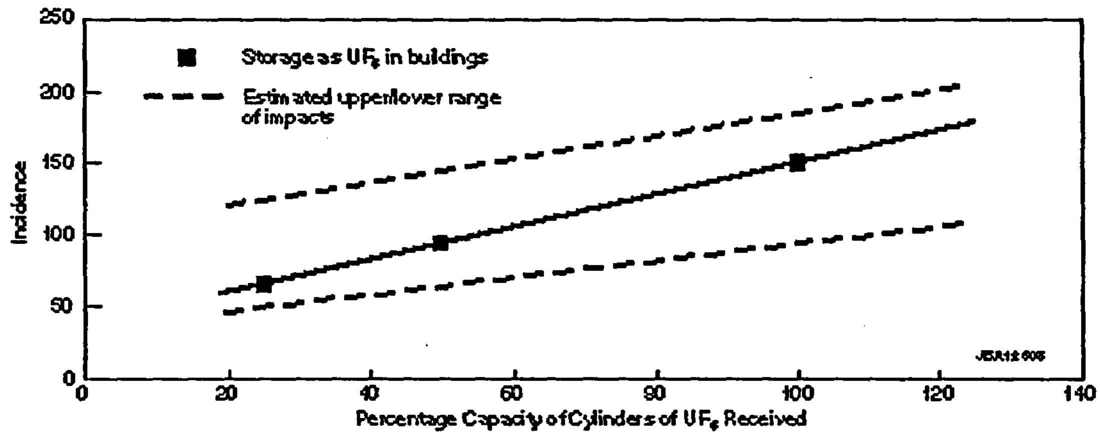

FIGURE K.35 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) for Storage as UF_6 (The ranges reflect differences in storage technologies, i.e., buildings, yards, and mine.)

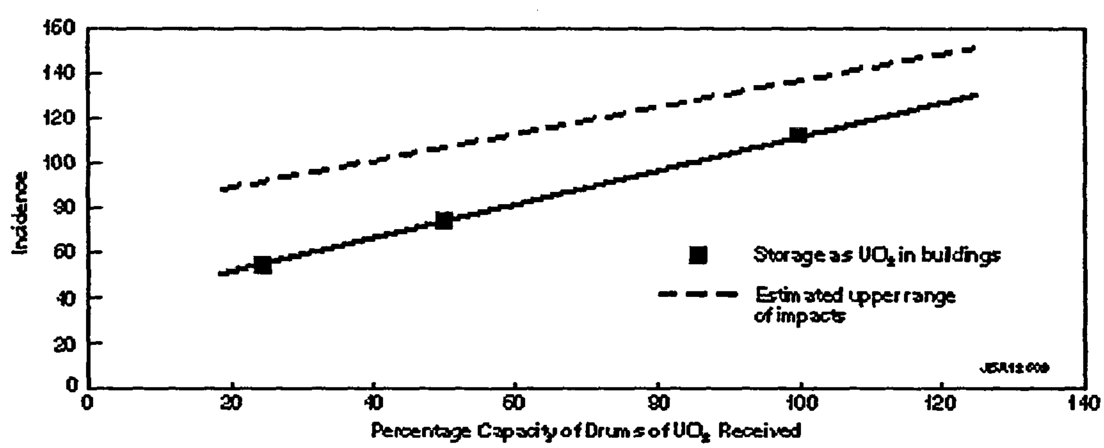

FIGURE K.36 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) for Storage as UO_2 (The ranges reflect differences in storage technologies, i.e., buildings, vaults, and mine.)

K.3.3 Air Quality

The estimated impacts on air quality during construction and operation of full-scale (100%) long-term storage facilities for UF_6 and oxide are presented in detail in Appendix G, Section G.3.3. All of the pollutant concentrations resulting from 100% throughput would be below the respective air quality standards. During construction, short-term particulate concentrations would potentially approach the applicable air quality standards for all options, although the condition would be temporary and minimized by good construction practices. During operations, the pollutant concentrations would be less than 0.1% of the corresponding air quality standards, resulting in negligible impacts.

The air quality impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases. During construction, short-term impacts for the parametric cases would be less than those for the 100% cases; impacts during operations would also be negligible. The air quality impacts from storage were found to scale roughly proportionally with throughput. The impacts from the 50% case for both construction and operations would be about 0.6 of those from the 100% case for both UF_6 and UO_2; the impacts for construction for the 25% case would be 0.25 and 0.32 times the 100% case for UF_6 and UO_2, respectively; and the impacts for operations for the 25% case would be only about 0.2 times the 100% case for both UF_6 and UO_2.

K.3.4 Water and Soil

K.3.4.1 Surface Water

The estimated impacts on surface water during construction, operation, and potential accidents for full-scale (100%) storage facilities for UF_6 and oxide are presented in detail in Appendix G, Section G.3.4.1. The potential impacts evaluated included changes in runoff, changes in quality, and floodplain encroachment. The impacts to surface water from the 100% cases were found to be negligible for all storage options for both UF_6 and oxide (including storage of U_3O_8). The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.3.4.2 Groundwater

The estimated impacts on groundwater during construction, operation, and potential accidents for full-scale (100%) storage facilities for UF_6 and oxide are presented in detail in Appendix G, Section G.3.4.2. The potential impacts evaluated included changes in depth to groundwater, direction of groundwater flow, recharge, and groundwater quality. The impacts to groundwater from the 100% cases were found to be negligible for all storage options for both UF_6

and oxide (including storage of U_3O_8). The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.3.4.3 Soil

The estimated impacts to soil during construction, operation, and potential accidents for full-scale (100%) long-term storage facilities for UF_6 and oxide are presented in detail in Appendix G, Section G.3.4.3. The potential impacts evaluated included changes in topography, permeability, quality, and erosion potential. The impacts to soil from the 100% cases were found to have potentially moderate, but temporary, impacts for all storage options. These moderate impacts would result from material excavated during construction that would be left on-site. In the long term, contouring and reseeding would return soil conditions back to their former state, and the impacts would be negligible. The impacts calculated for the 25% and 50% parametric cases for storage of UF_6 and UO_2 in buildings, based on information provided in the engineering analysis report (LLNL 1997a), were also found to have moderate, but temporary, impacts on soil, similar to the 100% cases. In the long term, impacts on soil would be negligible for all storage options.

K.3.5 Socioeconomics

The socioeconomic impacts of UF_6 and UO_2 long-term storage facilities for the 50% and 25% parametric cases would be less than the impacts of the base-case facility sizes. Cost information was not available in sufficient detail to allow an analysis of impacts using the same methodology that was used for the base cases. The impacts of parametric cases were therefore assessed qualitatively, based on the assumption that changes in the cost of equipment, materials, and labor would be proportional to changes in total life-cycle cost. Compared with base-case facility sizes, smaller UF_6 and UO_2 long-term storage facilities would result in the following: less direct and indirect employment and income in the ROI would be created at each representative site; fewer people would migrate into the ROI with fewer total jobs created, meaning fewer rental and owner-occupied houses would be needed; and the impact on local jurisdictional revenues and expenditures would be smaller.

K.3.6 Ecology

Impacts to ecological resources could occur during construction of UF_6 storage facilities for all options, although impacts during operations would be negligible. Impacts due to construction and operation of a facility to store UO_2 in buildings would be similar to impacts from storage of UF_6. Site preparation activities would result in the disturbance of biotic communities, including the permanent replacement of habitat with structures and paved areas (see

Section K.3.9). Existing vegetation would be destroyed during land-clearing activities. Wildlife would be disturbed by land clearing, noise, and human presence.

Depending on the exact location of the UF_6 facility, the loss of 40 to 130 acres (16 to 53 ha) of undeveloped land and habitat might constitute a moderate to large adverse impact to vegetation and wildlife. (See Section K.3.9 for details on land use assumptions.) Depending on the exact location of the UO_2 facility, the loss of 40 to 80 acres (16 to 32 ha) of undeveloped land and habitat might constitute a moderate adverse impact. However, when these facilities were sited, all appropriate measures would be taken to preclude or minimize such impacts.

Impacts to wetlands and state and federally protected species due to facility construction would depend on facility location. Avoidance of wetland areas and site-specific surveys for protected species would be included during facility planning.

K.3.7 Waste Management

The estimated impacts from waste management operations from the construction and operation of full-scale (100%) long-term storage facilities for UF_6 and oxide are presented in detail in Appendix G, Section G.3.7. On the basis of information provided in the engineering analysis report (LLNL 1997a), the impacts resulting from construction and operation of the long-term storage facility for the 25% and 50% parametric cases would be roughly linear for throughput ranges of between 25% and 100%. Minimal to moderate, but temporary, waste management impacts would result from construction wastes. Negligible impacts would be associated with all waste forms generated during operations. Overall, the waste input resulting from storage facilities would have negligible impact on waste management capacities locally or across the DOE complex.

K.3.8 Resource Requirements

The estimated impacts from resource requirements during construction and operation of full-scale (100%) long-term storage facilities for UF_6 and oxide are presented in detail in Appendix G, Section G.3.8. The impacts on resources would be expected to be small for the 100% capacity storage case for all options. Resource requirements for the two parametric cases considered would be less than those for the 100% case (LLNL 1997a). In general, the amounts of construction materials would be roughly proportional to the storage capacity because the majority of the construction materials would be for the actual storage buildings and the number of storage buildings required would be linearly related to the required storage capacity.

Construction and operation of the proposed storage facilities would consume irretrievable amounts of electricity, fuel, concrete, steel and other metals, water, and miscellaneous chemicals. The total quantities of commonly used materials would not be expected to be significant. No strategic and critical materials (e.g., Monel or Inconel) in significant quantities are projected to be consumed during construction or operation for all long-term storage options. The storage options are not considered resource-intensive, and the resources required are generally not considered rare or unique. Furthermore, committing any of these resources would not be expected to cause a negative impact on the availability of these resources within local areas or nationally for the 100%, 50%, and 25% cases.

K.3.9 Land Use

Impacts to land use from the construction and operation of UF_6 storage buildings would be limited to the clearing of required land, potential minor and temporary disruptions to contiguous land parcels, and a slight increase in vehicular traffic. Site preparation for construction of a facility to store 25%, 50%, and 100% of the depleted UF_6 inventory in buildings would require the disturbance of approximately 42, 72, and 131 acres (17, 29, and 53 ha), respectively. Within this disturbed area, the facility would require the permanent replacement of approximately 16, 30, and 62 acres (6.5, 12, and 25 ha) with structures and paved areas. The amount of land required for the other UF_6 storage options would be generally similar.

Land for storage buildings would be cleared incrementally over the projected 20-year construction project, thereby reducing the potential for land disturbance and consequential land disruption impacts. Such potential impacts, however, would be greatest at 100% of throughput capacity. Also, the areal requirement of 131 acres (53 ha) for the 100% capacity case could result in land-use changes if an existing site with limited open space were chosen.

Road and rail access within a storage site would be designed to minimize on-site traffic conflicts. For off-site traffic, only temporary, minor impacts associated with construction vehicles would be expected.

Storage as UO_2 would be expected to generate only negligible impacts to land use and would result in a lower areal requirement and less land disturbance compared with storage as UF_6. Site preparation for the construction of a facility to store 25%, 50%, and 100% of the depleted UF_6 inventory as UO_2 in buildings would require the disturbance of approximately 37, 49, and 79 acres (15, 20, and 32 ha), respectively. Within this disturbed area, the facility would require the permanent replacement of approximately 13, 20, and 35 acres (5.1, 8.1, and 14 ha) with structures and paved areas. The amount of land required for the other uranium oxide storage options would be generally similar.

Land for storage buildings would be cleared incrementally over the projected 20-year construction project, thereby reducing the potential for land disturbance and consequential land disruption impacts. Such potential impacts, however, would be greatest at 100% of throughput capacity. The peak labor force during the 20-year construction period, regardless of throughput capacity, would not be large enough to generate other than negligible off-site traffic impacts.

K.3.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts could potentially occur if the long-term storage options considered in this PEIS were implemented — including impacts to cultural resources and environmental justice, as well as to aesthetics (e.g., visual environment), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of storage facilities. These impacts, although considered, were not analyzed in detail for one or both of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier NEPA documentation when specific sites are considered.

- Consideration of the impacts would not contribute to differentiation among the alternatives; therefore, it would not affect the decisions to be made in the Record of Decision that will be issued following publication of this PEIS.

K.4 MANUFACTURE AND USE OPTIONS

The parametric analysis of the manufacture and use options considered the environmental impacts of using 25% and 50% of the depleted UF_6 inventory in the form of either uranium metal or dense UO_2 to manufacture uranium-shielded casks. The analysis of both options (uranium metal or dense UO_2) was based on the assumption that depleted uranium would be used as the primary shielding material in containers, called "casks," used to store spent nuclear fuel. The assessment considered the environmental impacts that would occur during (1) construction of a cask manufacturing facility, (2) routine operation of the cask manufacturing facility, and (3) potential manufacturing plant accidents. The manufacturing of casks was assumed to take place over a 20-year period, from 2009 through 2028. Impacts during use of depleted uranium shielded casks were not estimated in the PEIS.

The areas of impact and the methodologies used to evaluate the parametric cases for the manufacture and use options were the same as those used to evaluate the 100% cases. The evaluation of the 100% cases is presented in detail in Appendix H. The supporting engineering data for the 25% and 50% parametric cases are provided in the engineering analysis report (LLNL 1997a).

K.4.1 Human Health — Normal Operations

K.4.1.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from normal operation of a full-scale (100%) UO_2 cask manufacturing facility are described in Appendix H, Section H.3.1.1. Similar impacts were calculated for the manufacture of casks using 50% and 25% of the depleted UF_6 inventory. The radiological impacts estimated for the 100%, 50%, and 25% case are shown in Figures K.37 through K.42 as radiation doses to each of the six receptor scenarios considered in the PEIS: members of the general public — annual collective dose and annual dose to the MEI; noninvolved workers — annual collective dose and annual dose to the MEI; and involved workers — annual collective dose and annual average individual dose. Because the radiological impacts to involved workers (Figures K.41 and K.42) would not depend on the location of the manufacturing facility, no ranges of impact are presented. Ranges of impacts are presented for noninvolved workers and the general public in Figures K.37 through K.40. The range of impacts for noninvolved workers would be related only to possible differences in site meteorological conditions. The impact range for members of the general public would be related to differences in both meteorological conditions and population density (i.e., from rural to urban areas).

The results of the parametric analysis (as shown in Figures K.37 through K.42) indicate that the collective radiological impacts would scale relatively linearly with the total quantity of depleted UF_6 used to manufacture the casks. The impacts of the 25% and 50% cases would be smaller than those for the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than half of the impacts for the 100% case). The doses shown in the figures can be converted to the number (or risk) of LCFs by multiplying the doses (in rem or person-rem) by 0.0005 LCF/person-rem for members of the public and 0.0004 LCF/person-rem for workers. Additional discussion of the significance of the estimated doses is provided in Appendix H, Section H.3.1.1.

The estimated radiation doses from the manufacture of uranium metal casks for the 100%, 50%, and 25% throughput cases are presented in Figures K.43 through K.48. The general relationship between radiological impacts and throughput would be similar to that for UO_2 casks; that is, the radiological impacts would decrease with decreasing throughput, although at a rate not proportional to the reduction in throughput.

K.4.1.2 Chemical Impacts

The estimated impacts from chemical exposures during the normal operation of full-scale (100%) cask manufacturing facilities for UO_2 and uranium metal are described in Appendix H, Section H.3.1.2. The results of the 100% case analyses indicated that noninvolved workers and members of the general public would receive very low exposures to chemicals from the normal

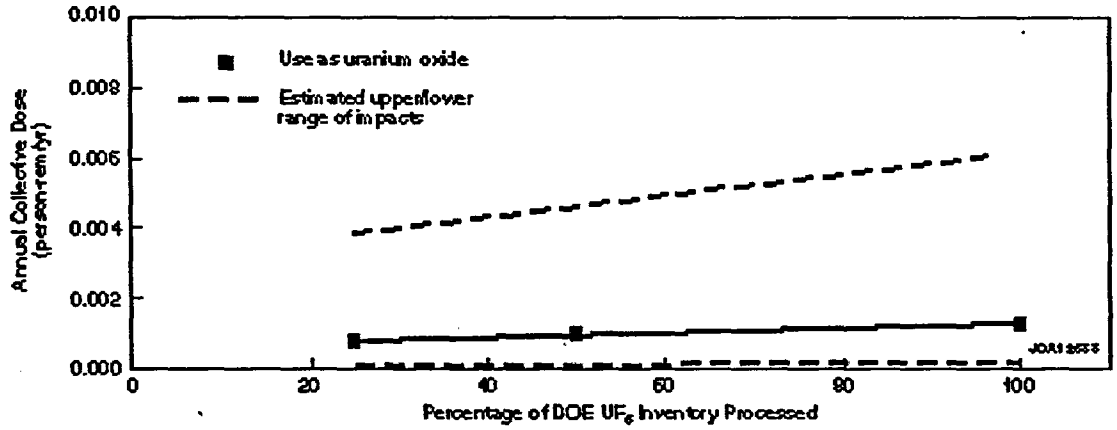

FIGURE K.37 Estimated Annual Collective Dose to Members of the Public from the Manufacture of Casks Using UO_2 (The upper and lower ranges reflect differences in site characteristics, such as meteorological conditions and rural or urban area.)

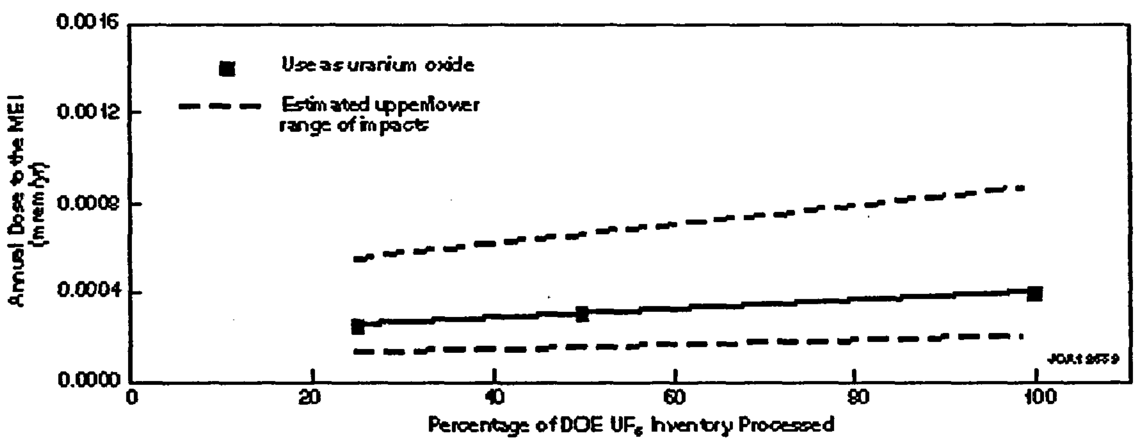

FIGURE K.38 Estimated Annual Dose to the General Public MEI from the Manufacture of Casks Using UO_2 (The upper and lower ranges reflect differences between site characteristics, primarily meteorological conditions.)

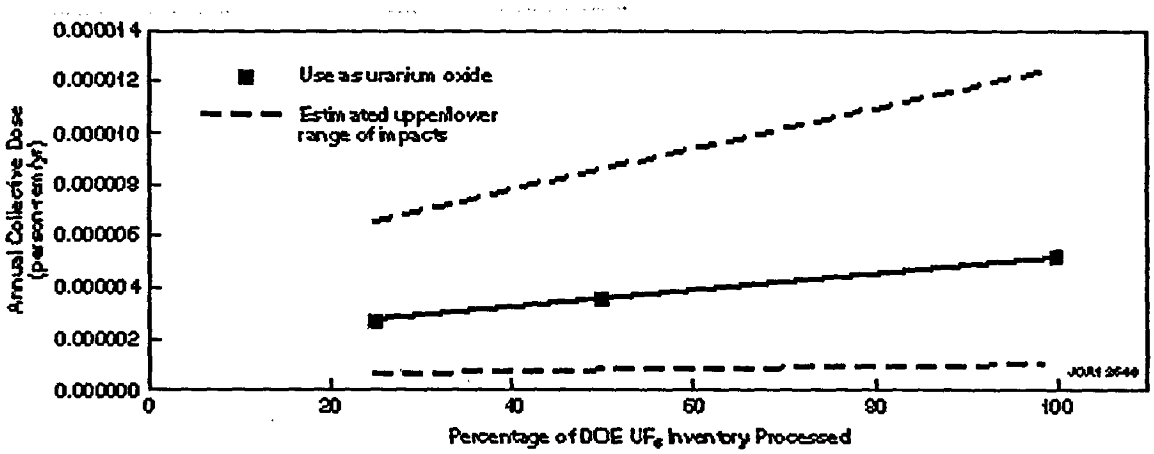

FIGURE K.39 Estimated Annual Collective Dose to Noninvolved Workers from the Manufacture of Casks Using UO_2 (The upper and lower ranges reflect differences in site characteristics, primarily meteorological conditions.)

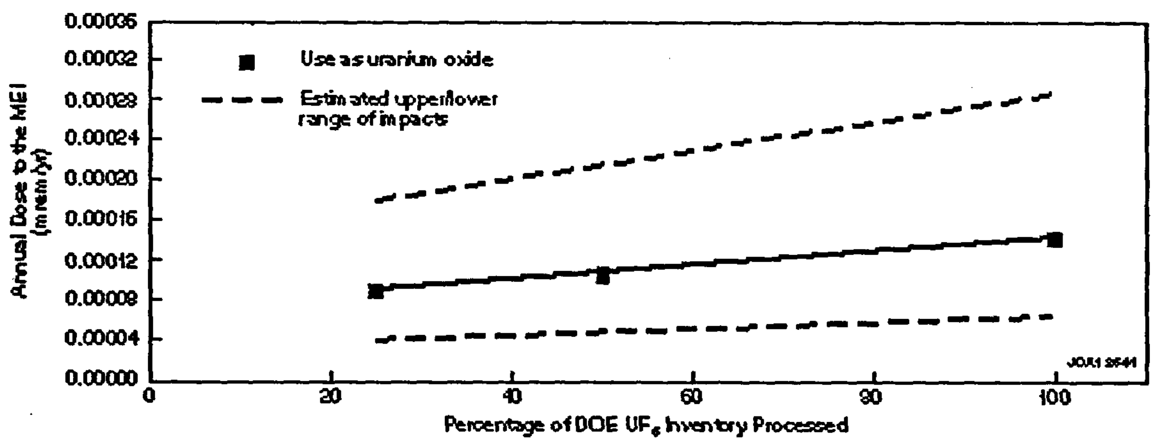

FIGURE K.40 Estimated Annual Dose to the Noninvolved Worker MEI from the Manufacture of Casks Using UO_2 (The upper and lower ranges reflect differences in site characteristics, primarily meteorological conditions.)

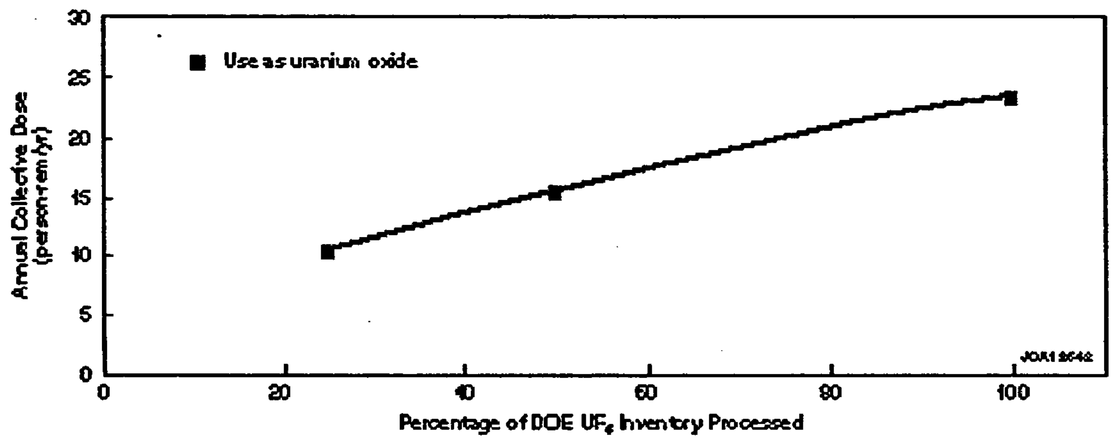

FIGURE K.41 Estimated Annual Collective Dose to Involved Workers from the Manufacture of Casks Using UO_2

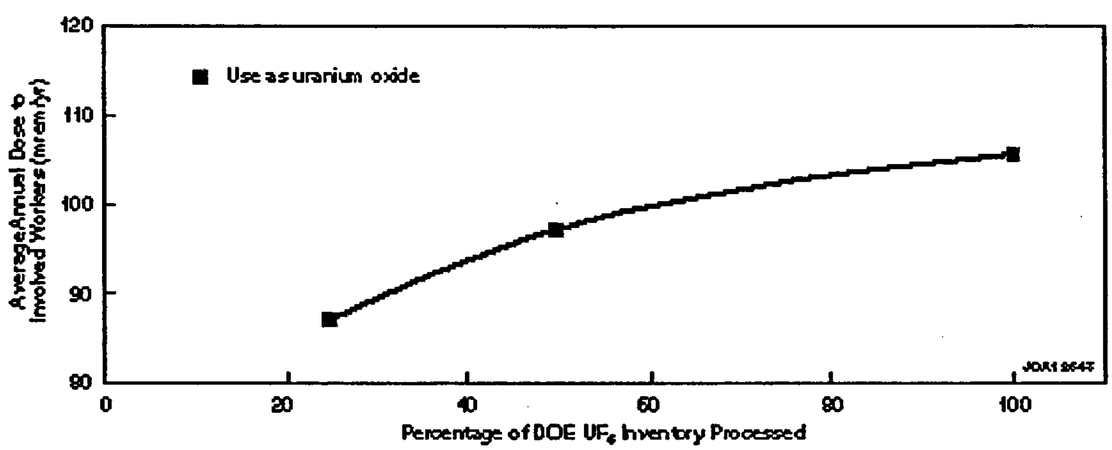

FIGURE K.42 Estimated Annual Average Individual Dose to Involved Workers from the Manufacture of Casks Using UO_2

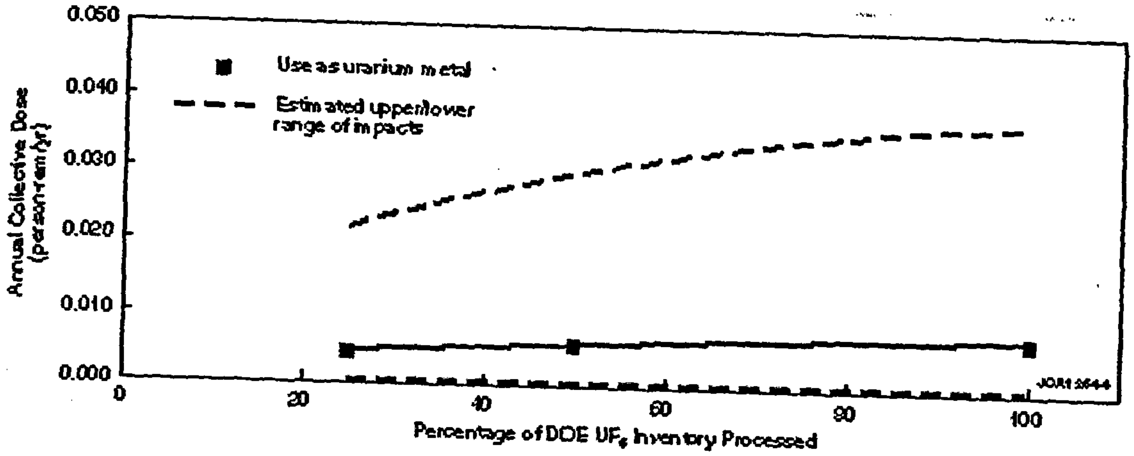

FIGURE K.43 Estimated Annual Collective Dose to Members of the Public from the Manufacture of Casks Using Uranium Metal (The upper and lower ranges reflect differences in site characteristics, such as meteorological conditions and rural or urban area.)

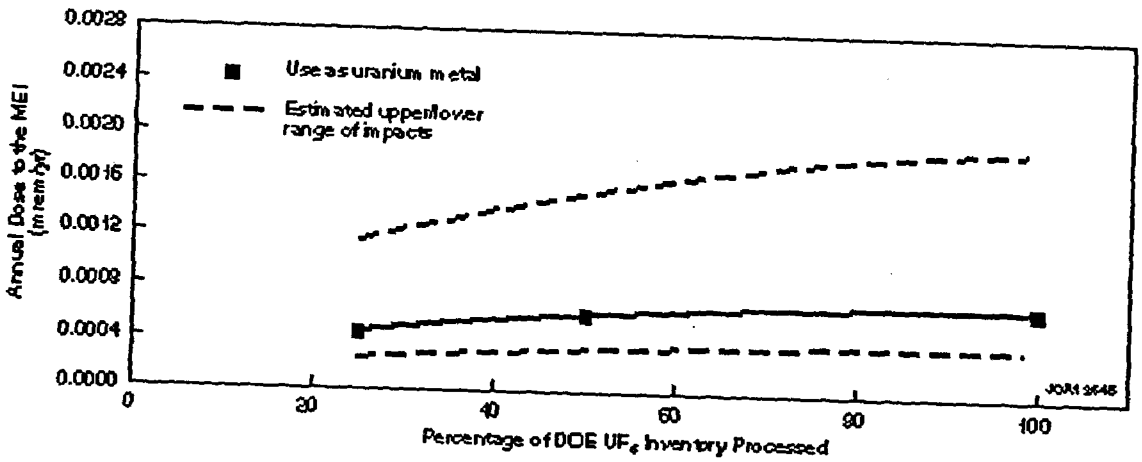

FIGURE K.44 Estimated Annual Dose to the General Public MEI from the Manufacture of Casks Using Uranium Metal (The upper and lower ranges reflect differences in site characteristics, primarily meteorological conditions.)

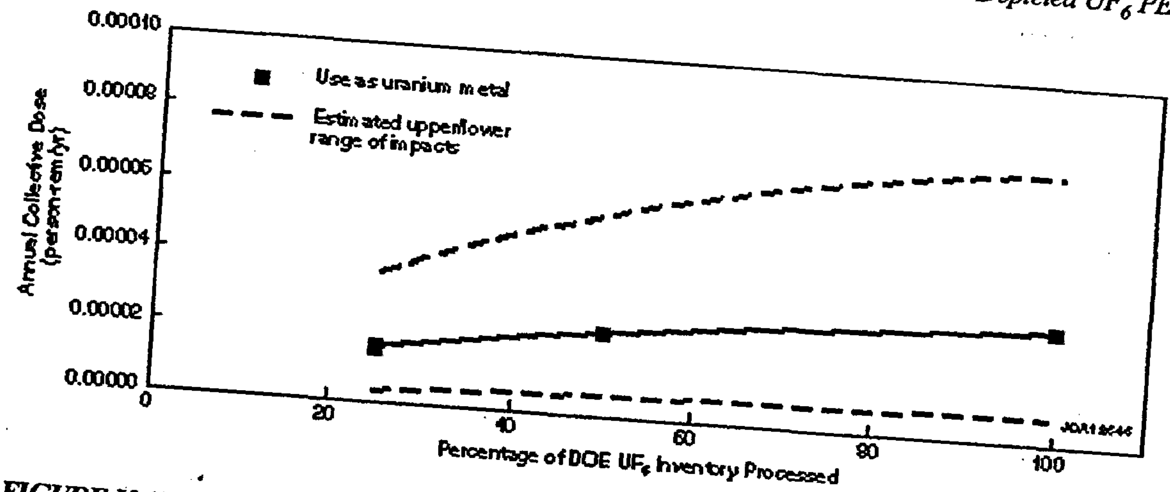

FIGURE K.45 Estimated Annual Collective Dose to Noninvolved Workers from the Manufacture of Casks Using Uranium Metal (The upper and lower ranges reflect differences in site characteristics, primarily meteorological conditions.)

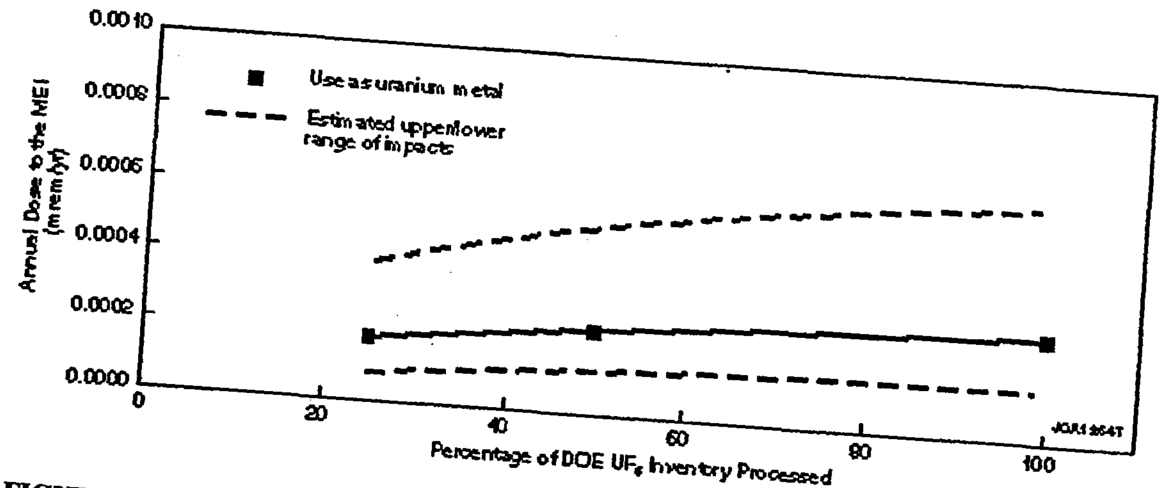

FIGURE K.46 Estimated Annual Dose to the Noninvolved Worker MEI from the Manufacture of Casks Using Uranium Metal (The upper and lower ranges reflect differences in site characteristics, primarily meteorological conditions.)

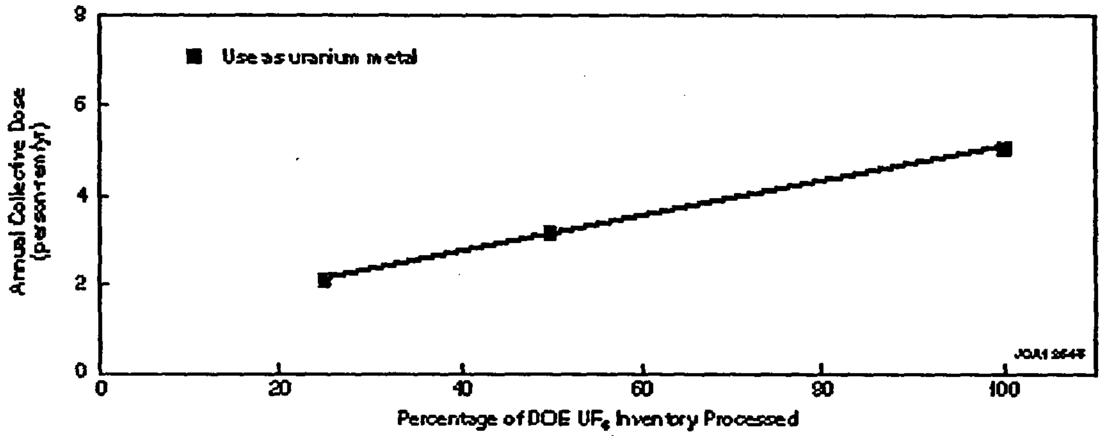

FIGURE K.47 Estimated Annual Collective Dose to Involved Workers from the Manufacture of Casks Using Uranium Metal

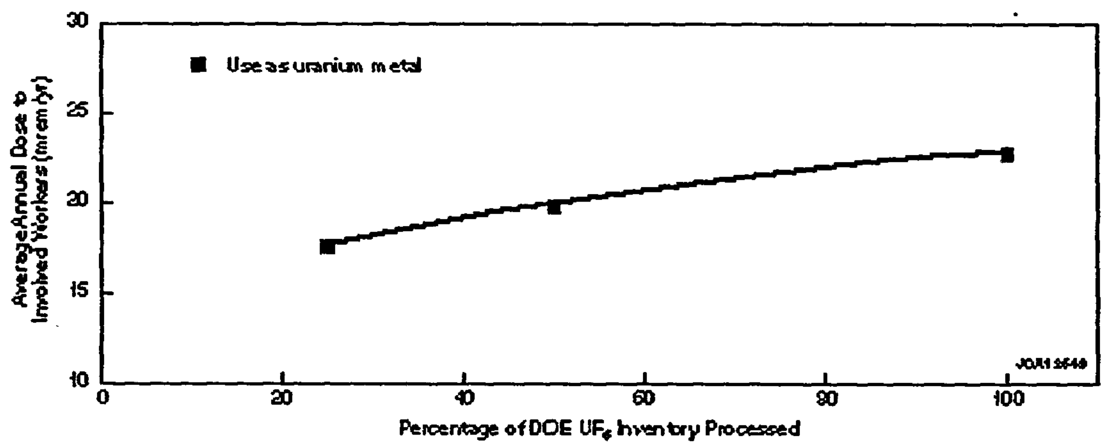

FIGURE K.48 Estimated Annual Average Individual Dose to Involved Workers from the Manufacture of Casks Using Uranium Metal

operation of manufacturing facilities and that no adverse health impacts would be expected. For the 100% cases, the calculated hazard indices were much less than 1 during normal operations (a hazard index of greater than 1 indicates the potential for health impacts). For the parametric analysis of the 25% and 50% throughput cases, airborne emissions during normal operations would be less than the 100% cases and extremely small (LLNL 1997a). Therefore, by comparison with the 100% case results, no adverse health impacts from chemical exposures would be expected for throughput rates between 25% and 100% for the manufacture of UO_2 and uranium metal shielded casks.

K.4.2 Human Health — Accident Conditions

K.4.2.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from potential accidents during the operation of full-scale (100%) cask manufacturing facilities are presented in Appendix H, Section H.3.2.1. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented only for those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

The impacts from bounding accidents for the 25% and 50% throughput cases would be the same as those presented in Appendix H, Section H.3.2.1 for the 100% case, with two exceptions. For the manufacture of both uranium oxide and uranium metal shielded casks, the bounding accident impacts for the "unlikely" frequency category would be less for the 25% and 50% cases than for the 100% case. The radiological impacts for these accident categories are presented in Tables K.3 and K.4 for the 100%, 50%, and 25% cases.

K.4.2.2 Chemical Impacts

The estimated chemical impacts from potential accidents during the operation of full-scale (100%) cask manufacturing facilities using uranium oxide and uranium metal are presented in Appendix H, Section H.3.2.2. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented only for those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

The bounding chemical accidents associated with the 25% and 50% throughput cases would be the same as those presented for the 100% cases in Appendix H. The impacts would be similar because the bounding accidents within most frequency categories would be the same as

TABLE K.3 Estimated Radiological Doses per Accident Occurrence for the Manufacture and Use Options

			Maximum Dose[c]				Minimum Dose[c]			
			Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Option/ Accident[a]	Frequency Category[b]	Capacity (%)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Use as Uranium Oxide Casks										
Earthquake	Unlikely	100	7.7×10^{-2}	2.9×10^{-2}	2.3×10^{-3}	3.2×10^{-1}	3.2×10^{-3}	1.2×10^{-3}	9.2×10^{-5}	1.1×10^{-3}
		50	3.9×10^{-2}	1.5×10^{-2}	1.1×10^{-3}	1.6×10^{-1}	1.6×10^{-3}	6.1×10^{-4}	4.6×10^{-5}	5.4×10^{-4}
		25	1.9×10^{-2}	7.3×10^{-3}	5.7×10^{-4}	7.9×10^{-2}	8.1×10^{-4}	3.0×10^{-4}	2.3×10^{-5}	2.7×10^{-4}
Use as Uranium Metal Casks										
Earthquake	Unlikely	100	1.1×10^{-2}	4.3×10^{-3}	3.4×10^{-4}	4.6×10^{-2}	4.7×10^{-4}	1.8×10^{-4}	1.3×10^{-5}	1.6×10^{-4}
		50	5.5×10^{-3}	2.2×10^{-3}	1.7×10^{-4}	2.3×10^{-2}	2.3×10^{-4}	9.0×10^{-5}	6.5×10^{-6}	8.0×10^{-5}
		25	2.8×10^{-3}	1.1×10^{-3}	8.5×10^{-5}	1.2×10^{-2}	1.2×10^{-4}	4.5×10^{-5}	3.3×10^{-6}	4.0×10^{-5}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[b] An unlikely accident is estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr).

[c] Maximum and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

TABLE K.4 Estimated Radiological Health Risks per Accident Occurrence for the Manufacture and Use Options

Option/ Accident[a]	Frequency Category[b]	Capacity (%)	Maximum Risk[c] (LCFs)				Minimum Risk[c] (LCFs)			
			Noninvolved Workers		General Public		Noninvolved Workers		General Public	
			MEI	Population	MEI	Population	MEI	Population	MEI	Population
Use as Uranium Oxide Casks										
Earthquake	Unlikely	100	3×10^{-5}	1×10^{-5}	1×10^{-6}	2×10^{-4}	1×10^{-6}	5×10^{-7}	5×10^{-8}	5×10^{-7}
		50	2×10^{-5}	6×10^{-6}	6×10^{-7}	8×10^{-5}	6×10^{-7}	2×10^{-7}	2×10^{-8}	3×10^{-7}
		25	8×10^{-6}	3×10^{-6}	3×10^{-7}	4×10^{-5}	3×10^{-7}	1×10^{-7}	1×10^{-8}	1×10^{-7}
Use as Uranium Metal Casks										
Earthquake	Unlikely	100	4×10^{-6}	2×10^{-6}	2×10^{-7}	2×10^{-5}	2×10^{-7}	7×10^{-8}	7×10^{-9}	8×10^{-8}
		50	2×10^{-6}	9×10^{-7}	8×10^{-8}	1×10^{-5}	1×10^{-7}	4×10^{-8}	3×10^{-9}	4×10^{-8}
		25	1×10^{-6}	4×10^{-7}	4×10^{-8}	6×10^{-6}	5×10^{-8}	2×10^{-8}	2×10^{-9}	2×10^{-8}

[a] The accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[b] An unlikely accident is estimated to occur between once in 100 years and once in 10,000 years of facility operations ($10^{-2} - 10^{-4}$/yr).

[c] Maximum and minimum doses reflect differences in assumed sites, technologies, and meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed.

the 100%, 50%, and 25% cases, and in those cases where these accidents were different, no adverse chemical impacts were estimated to occur. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. Some of the impacts from other accidents considered for the 25% and 50% cases (nonbounding) would be different from those for the 100% cases. In general, the impacts of these nonbounding accidents for the 50% and 25% cases would be less than those for the 100% cases because of the reduced throughput.

K.4.2.3 Physical Hazards

The estimated health impacts, such as on-the-job injuries and fatalities, from potential physical accidents during the construction and operation of full-scale (100%) cask manufacturing facilities are presented in Appendix H, Section H.3.2.3. For the 100% analysis, up to 1 on-the-job fatality was predicted for the manufacture of both uranium oxide and uranium metal shielded casks. The predicted number of on-the-job worker injuries for the 100% case was 640 for manufacturing uranium oxide shielded casks and 670 for uranium metal shielded casks. For the two options analyzed in detail in the parametric analysis, the impacts of the 25% and 50% cases would be smaller than those for the 100% cases, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than 50% of the impacts for the 100% case).

The predicted number of on-the-job worker fatalities over the entire 20 years of the manufacture of uranium oxide or uranium metal shielded casks is about 1 (including construction and operations). For uranium oxide shielded casks, the number would range from 0.6 for the 25% case to 0.76 for the 100% case; whereas for uranium metal shielded casks, the number would range from 0.7 for the 25% case to 0.85 for the 100% case. The predicted number of on-the-job injuries (including construction and operations) would range from 480 to 640 for uranium oxide casks and from 510 to 670 for uranium metal casks. The estimated numbers of fatalities and injuries for uranium oxide and uranium metal shielded casks are shown as a function of throughput in Figures K.49 and K.50, respectively.

K.4.3 Air Quality

The estimated impacts on air quality during construction and operation of full-scale (100%) cask manufacturing facilities are presented in detail in Appendix H, Section H.3.3. All of the pollutant concentrations produced by the 100% capacity version of the storage facilities would be below their respective air quality standards. During construction, the largest impacts relative to air quality standards would occur for nitrogen oxides (NO_x). During construction, all pollutant concentrations would be less than 10% of the corresponding standards. During operations, all pollutant concentrations would also be less than 10% of the standards.

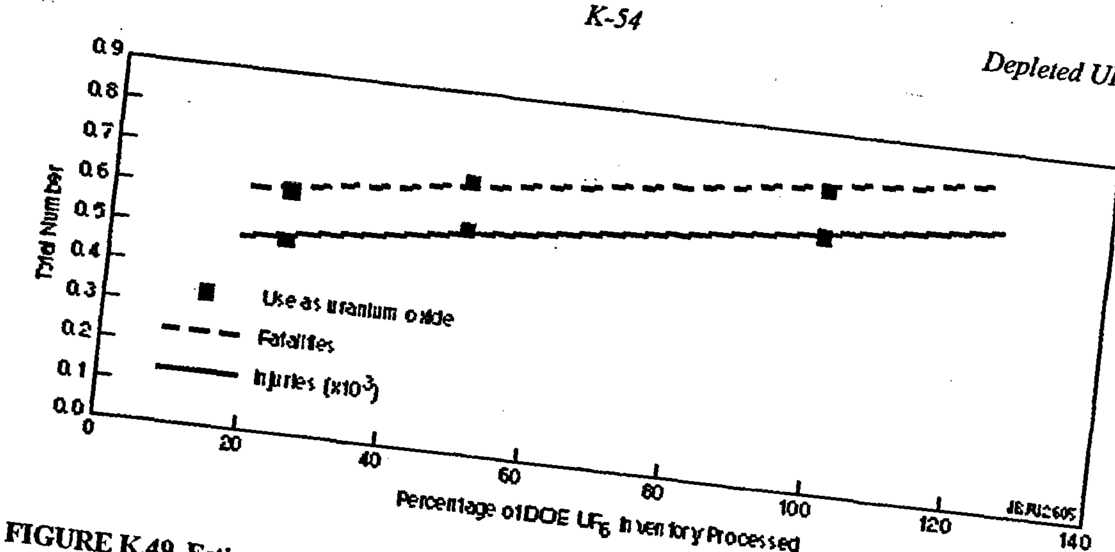

FIGURE K.49 Estimated Number of On-the-Job Fatalities and Injuries (for entire construction and operational periods) from the Manufacture of Uranium Oxide Shielded Casks

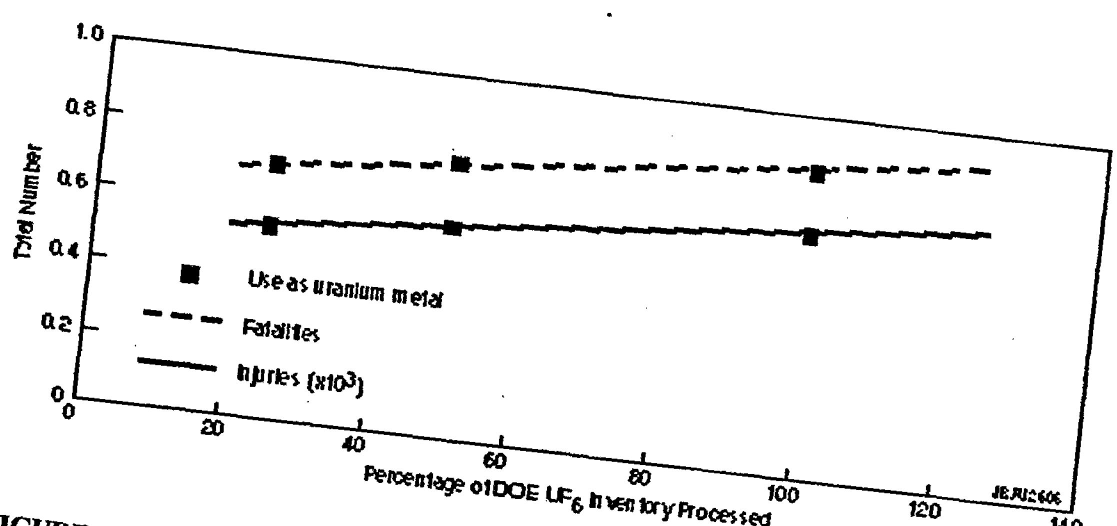

FIGURE K.50 Estimated Number of On-the-Job Fatalities and Injuries (for entire construction and operational periods) from the Manufacture of Uranium Metal Shielded Casks

The air quality impacts calculated for the 25% and 50% parametric cases, based on the information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases. During construction, short-term impacts for the parametric cases would be less than those for the 100% cases, and impacts during operations would also be less. The 25% case impacts would not be much smaller than the 50% case impacts, and the operations impacts in all cases would be less than 10% of the corresponding construction impacts.

K.4.4 Water and Soil

K.4.4.1 Surface Water

The estimated impacts on surface water during construction, operation, and potential accidents for full-scale (100%) cask manufacturing facilities are presented in detail in Appendix H, Section H.3.4. The potential impacts evaluated included changes in runoff, changes in quality, and floodplain encroachment. The impacts to surface water from the 100% cases were found to be negligible for manufacturing both uranium oxide and uranium metal shielded casks. The impacts estimated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.4.4.2 Groundwater

The estimated impacts on groundwater during construction, operation, and potential accidents for full-scale (100%) cask manufacturing facilities are presented in detail in Appendix H, Section H.3.4. The potential impacts evaluated included changes in the depth to groundwater, the direction of groundwater flow, recharge, and quality. The impacts to groundwater from the 100% cases were found to be negligible for manufacturing both uranium oxide and uranium metal shielded casks. The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.4.4.3 Soil

The estimated impacts to soil during construction, operation, and potential accidents for full-scale (100%) cask manufacturing facilities are presented in detail in Appendix H, Section H.3.4. The potential impacts evaluated included changes in topography, permeability, quality, and erosion potential. The impacts to soil from the 100% cases were found to be negligible for manufacturing both uranium oxide and uranium metal shielded casks. The impacts calculated for the 25% and 50%

parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% cases, and thus would also be negligible.

K.4.5 Socioeconomics

The socioeconomic impacts of UO_2 and metal manufacturing facilities for the 25% and 50% parametric cases would be less than the impacts of the base-case facility sizes. Cost information was not available in sufficient detail to allow an analysis of impacts using the same methodology that was used for the base cases. The impacts of parametric cases were therefore assessed qualitatively, based on the assumption that changes in the cost of equipment, materials, and labor would be proportional to changes in total life-cycle cost. Compared with base-case facility sizes, smaller UO_2 and metal manufacturing facilities would create less direct employment and income at the site.

K.4.6 Ecology

For both uranium oxide and uranium metal shielded cask manufacturing facilities, impacts to air quality, surface water, groundwater, and soil during construction and operations would be expected to be well below levels harmful to biota for the 25%, 50%, and 100% cases. Resulting contaminant-derived impacts to ecological resources would be expected to be negligible. Potential impacts to wetlands and state and federally protected species due to facility construction would depend on facility location. Avoidance of wetland areas would be included during facility planning. Site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Site preparation for the construction of cask manufacturing facilities would result in the disturbance of biotic communities, including the permanent replacement of habitat with structures and paved areas (see Section K.4.9). Existing vegetation would be destroyed during land-clearing activities. Wildlife would be disturbed by land clearing, noise, and human presence. Depending on the exact location of the uranium oxide or uranium metal cask manufacturing facility, the loss of 27 to 90 acres (11 to 36 ha) of undeveloped land and habitat might constitute a moderate impact to vegetation and wildlife. However, when the uranium oxide and uranium metal cask manufacturing facilities were sited, all appropriate measures would be taken to preclude or minimize such impacts to ecological resources.

K.4.7 Waste Management

The estimated impacts from waste management operations from the construction and operation of full-scale (100%) cask manufacturing facilities are presented in detail in Appendix H, Section H.3.7. The impacts on regional and national waste management operations from construction and operation of manufacturing facilities were found to be negligible for the 100% throughput case.

On the basis of information provided in the engineering analysis report (LLNL 1997a), the impacts resulting from construction and operation for the 25% and 50% parametric cases would be roughly linear for throughput ranges of between 25% and 100%. Minimal waste management impacts would result from wastes generated during either construction or operations. Overall, the waste input resulting from normal operations at the manufacturing facilities would have negligible impact on waste management capacities locally or across the DOE complex. No assumptions were made regarding the fate of the oxide- and metal-shielded casks after use.

K.4.8 Resource Requirements

The estimated impacts from resource requirements during construction and operation of full-scale (100%) cask manufacturing facilities are presented in detail in Appendix H, Section H.3.8. The impacts on resources would be expected to be small for the 100% capacity case. Resource requirements for the two parametric cases considered would be less than those for the 100% case (LLNL 1997a).

Construction and operation of the cask manufacturing facilities would consume irretrievable amounts of electricity, fuel, concrete, steel and other metals, water, and miscellaneous chemicals. The total quantities of commonly used materials would not be expected to be significant. No strategic and critical materials (e.g., Monel or Inconel) in significant quantities are projected to be consumed during construction or operation of the facilities. Although high-grade graphite would be required for the metal shielded cask (as a lining for the crucibles containing molten uranium), the amounts required would not be significant. The manufacturing facility requirements would not be resource-intensive, and the resources required are generally not considered rare or unique. Furthermore, committing any of these resources would not be expected to cause a negative impact on the availability of these resources within local areas or nationally for the 100%, 50%, and 25% cases.

K.4.9 Land Use

Impacts to land use from the construction and operation of a uranium oxide shielded cask manufacturing facility, regardless of throughput capacity case, would be potentially moderate but limited to temporary disruptions to contiguous land parcels and increases in vehicular traffic associated with construction activities. Site preparation for the construction of a uranium oxide shielded cask manufacturing facility for 25%, 50%, and 100% of the depleted UF_6 inventory would require approximately 79, 84, and 90 acres (32, 34, and 36 ha), respectively. Within this area, the facility would require the permanent replacement of approximately 27, 28, and 31 acres (11, 11, and 13 ha) with structures and paved areas. Off-site impacts could occur from peak-year construction force vehicles, especially if the site had limited access from existing roadways.

Impacts to land use from the uranium metal shielded cask manufacturing facility would be the same as those discussed for the construction and operation of a uranium oxide shielded cask manufacturing facility, with no difference in the magnitude of impacts when the three throughput capacity cases are compared. For off-site impacts, traffic patterns could experience potentially adverse level-of-service impacts during the 7-year construction period from the peak-year construction labor force.

K.4.10 Other Impacts Considered But Not Analyzed in Detail

Other impacts could potentially occur if the manufacture and use options considered in this PEIS were implemented — including impacts to cultural resources and environmental justice, as well as to aesthetics (e.g., visual environment), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of manufacturing facilities. These impacts, although considered, were not analyzed in detail for one or both of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier NEPA documentation when specific sites are considered.

- Consideration of the impacts would not contribute to differentiation among the alternatives; therefore, it would not affect the decisions to be made in the Record of Decision that will be issued following publication of this PEIS.

K.5 DISPOSAL OPTIONS

The parametric analysis of the disposal options considered the environmental impacts of disposing of 25% and 50% of the depleted UF_6 inventory as an oxide form. It was assumed that the uranium material would be actively placed into disposal units over a 20-year period (from 2009 through 2028). The assessment considered the environmental impacts that would occur during (1) construction of a disposal facility, (2) routine disposal facility operations, (3) potential disposal facility accidents, and (4) the post-closure phase, defined as 1,000 years in the future after the disposal facility had failed. The areas of impact and the methodologies used to evaluate the parametric cases were the same as those used to evaluate the 100% cases discussed in Appendix I. The supporting engineering data for the 25% and 50% parametric cases are provided in the engineering analysis report (LLNL 1997a).

The environmental impacts for the 100% disposal case are presented in Appendix I for (1) disposal of grouted and ungrouted U_3O_8 in shallow earthen structures, vaults, and a mine; and (2) disposal of grouted and ungrouted UO_2 in shallow earthen structures, vaults, and a mine. Two representative locations, described in Chapter 3 of the PEIS, were considered for each option: a "dry" location and a "wet" location. For purposes of the parametric analysis, disposal of ungrouted U_3O_8 in a mine at both wet and dry locations was considered in detail. This option was chosen to simplify the parametric analysis because all options were evaluated in detail for the 100% base case. Impacts for the other disposal options, such as disposal of UO_2 and disposal in shallow earthen structures and vaults, were inferred from the relationships among the options identified from the 100% case analysis and from the additional relationships identified by the detailed parametric analysis conducted for the disposal of grouted U_3O_8 in a mine.

K.5.1 Human Health — Normal Operations

K.5.1.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from the normal operation of a full-scale (100%) disposal facility are described in Appendix I, Section I.3.1.1. Similar impacts were calculated for the 50% and 25% disposal facilities for the parametric analysis. Radiological impacts were calculated for the operational phase, during which time material would be disposed of, and for the post-closure phase, assumed to be 1,000 years in the future after the disposal facility had failed.

K.5.1.1.1 Operational Phase

The radiological impacts estimated for the 100%, 50%, and 25% cases during the operational phase are shown in Figures K.51 through K.66 for all disposal options. The impacts have been presented for the disposal of both grouted and ungrouted U_3O_8 and UO_2 as a function of the amount of material requiring disposal. The disposal of ungrouted U_3O_8 or UO_2 would not result in any airborne or waterborne emissions during operations because the material would be delivered to the disposal facility in packages that would be disposed of without being opened. Therefore, for the disposal of ungrouted waste, no impacts would be expected to the noninvolved workers and the off-site general public. The range of impacts resulting from technology and site differences are presented by dashed lines in the figures. The results for the disposal of ungrouted U_3O_8 in a mine, the case selected for detailed analysis, are shown in Figures K.63 and K.64 as solid points, with a curve drawn between the points to indicate how the impacts would vary as a function of the percent of material requiring disposal. The area enclosed by the dashed lines in Figures K.51 through K.66 indicates the range of impacts expected for throughputs between 25% and 100%, taking into account both technology and site differences.

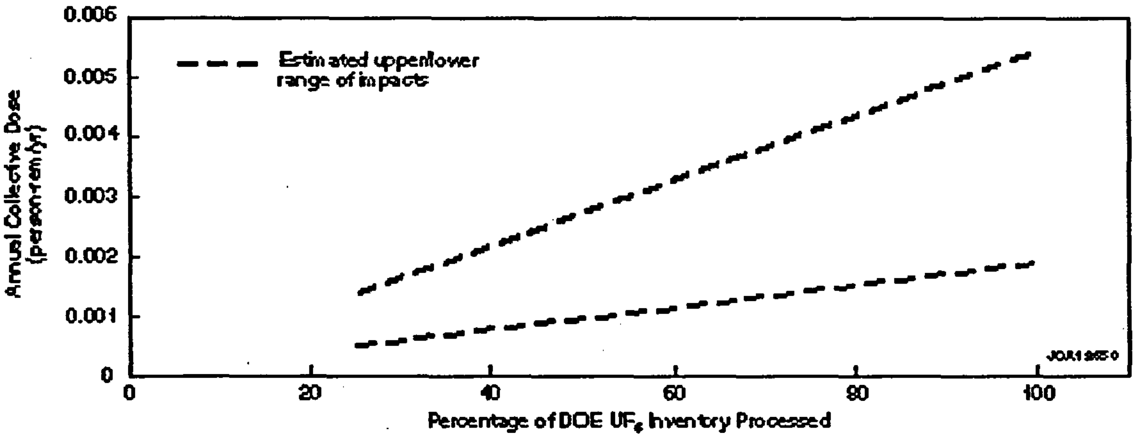

FIGURE K.51 Estimated Annual Collective Dose to Members of the Public from the Disposal of Grouted U_3O_8 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

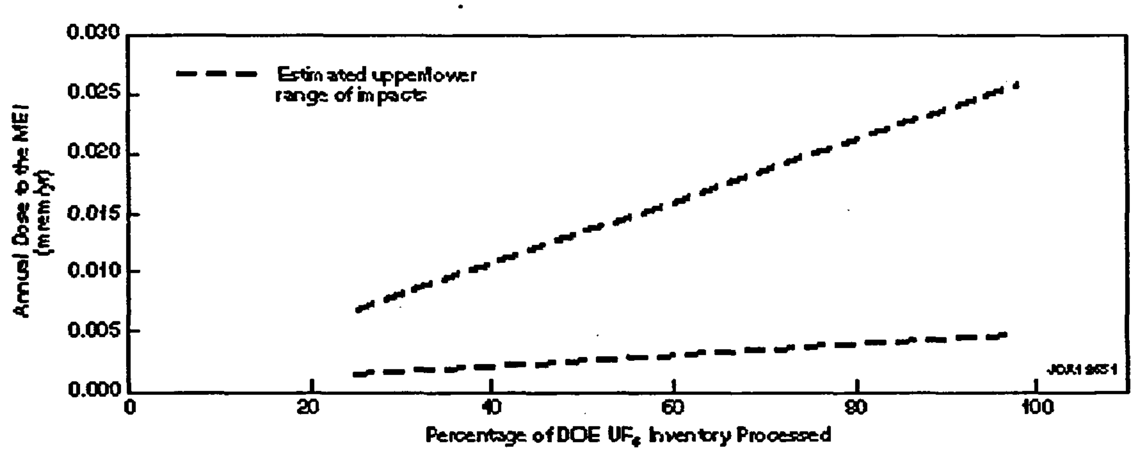

FIGURE K.52 Estimated Annual Dose to the General Public MEI from the Disposal of Grouted U_3O_8 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

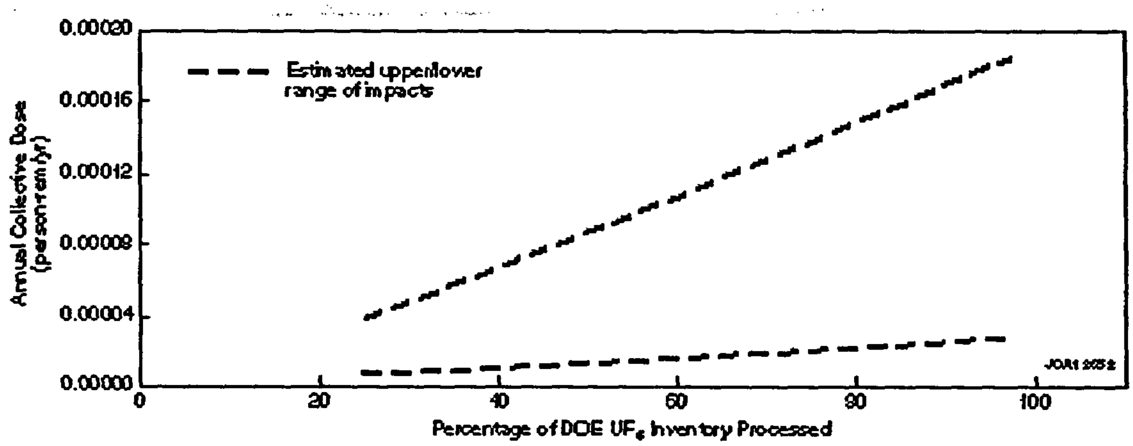

FIGURE K.53 Estimated Annual Collective Dose to Noninvolved Workers from the Disposal of Grouted U_3O_8 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

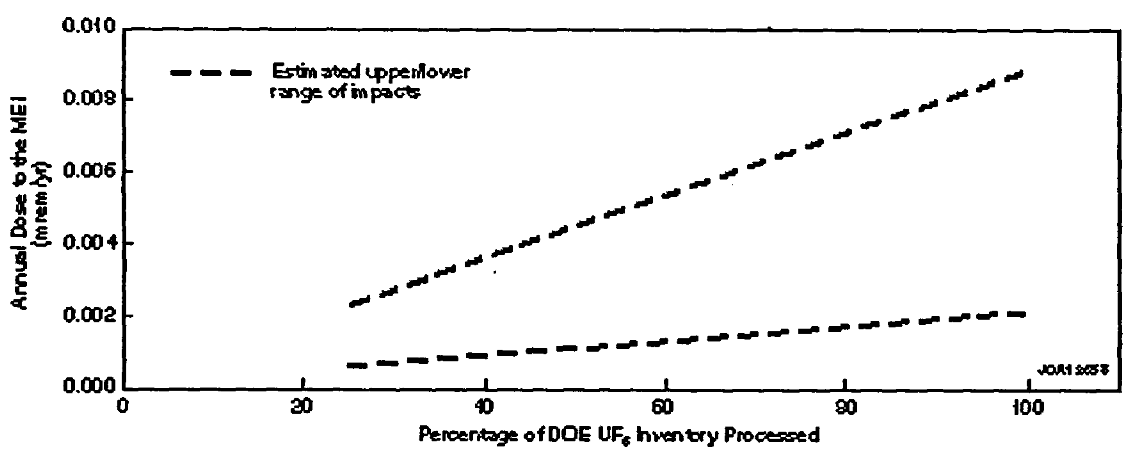

FIGURE K.54 Estimated Annual Dose to the Noninvolved Worker MEI from the Disposal of Grouted U_3O_8 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

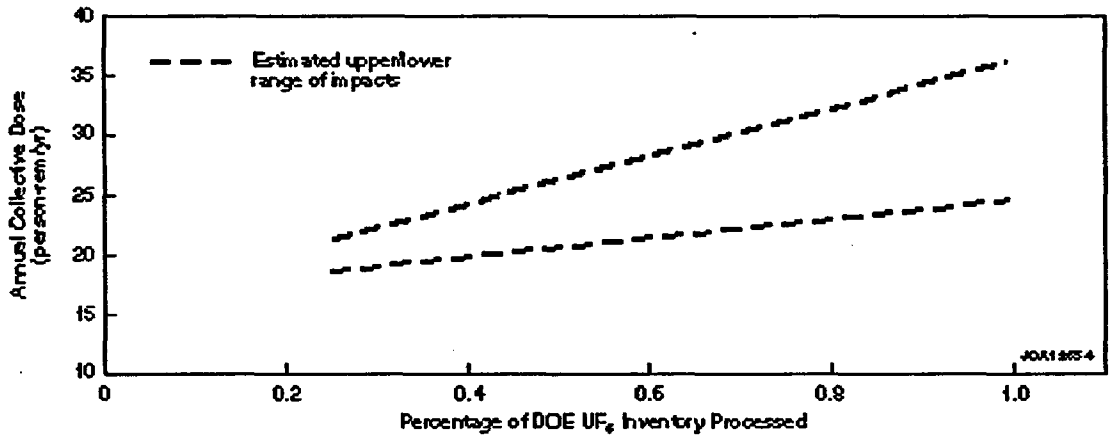

FIGURE K.55 Estimated Annual Collective Dose to Involved Workers from the Disposal of Grouted U_3O_8 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

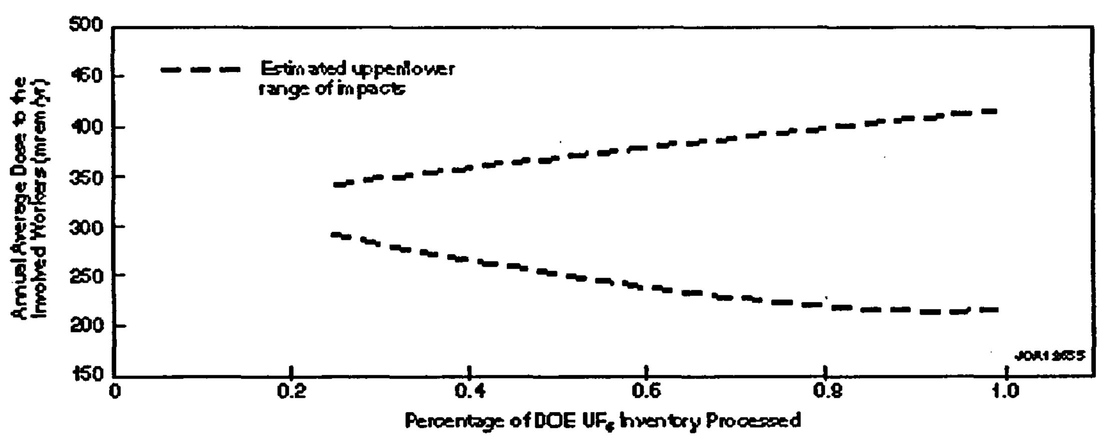

FIGURE K.56 Estimated Annual Average Individual Dose to Involved Workers from the Disposal of Grouted U_3O_8 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

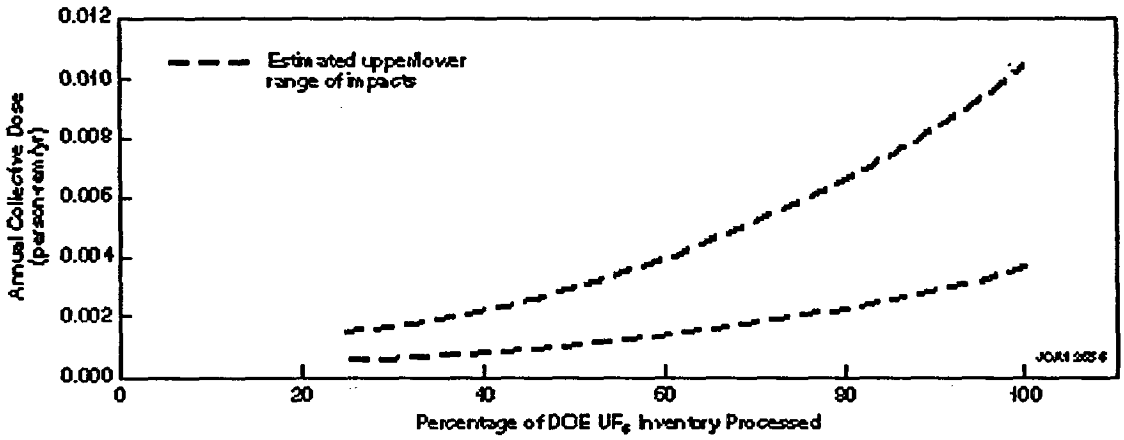

FIGURE K.57 Estimated Annual Collective Dose to Members of the Public from the Disposal of Grouted UO_2 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

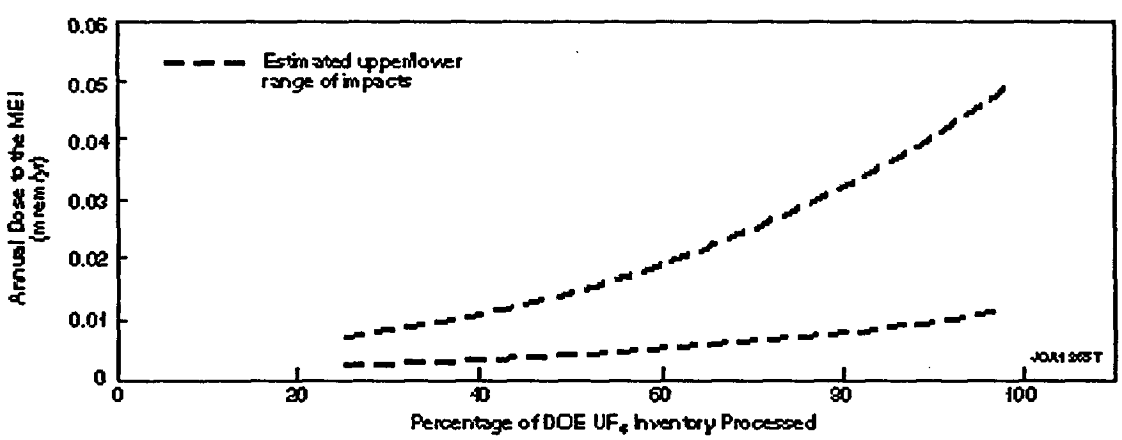

FIGURE K.58 Estimated Annual Dose to the General Public MEI from the Disposal of Grouted UO_2 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

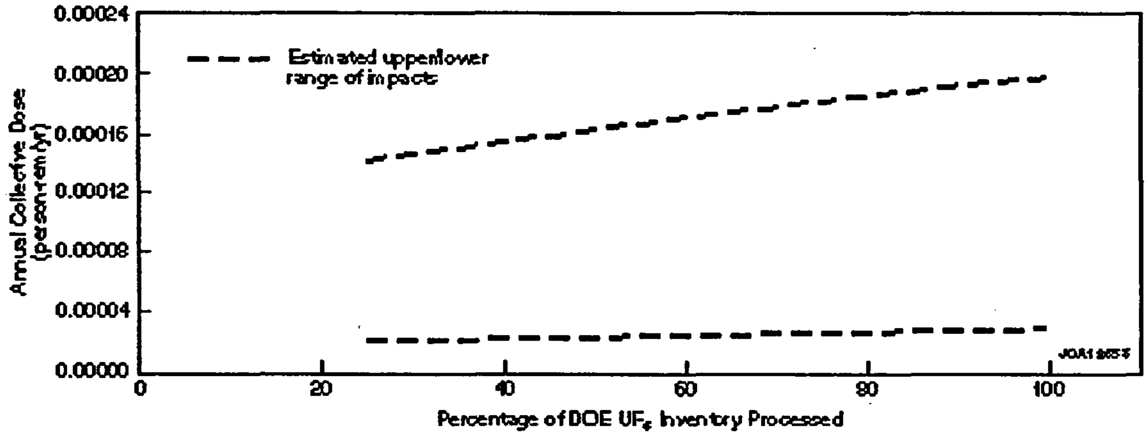

FIGURE K.59 Estimated Annual Collective Dose to Noninvolved Workers from the Disposal of Grouted UO_2 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

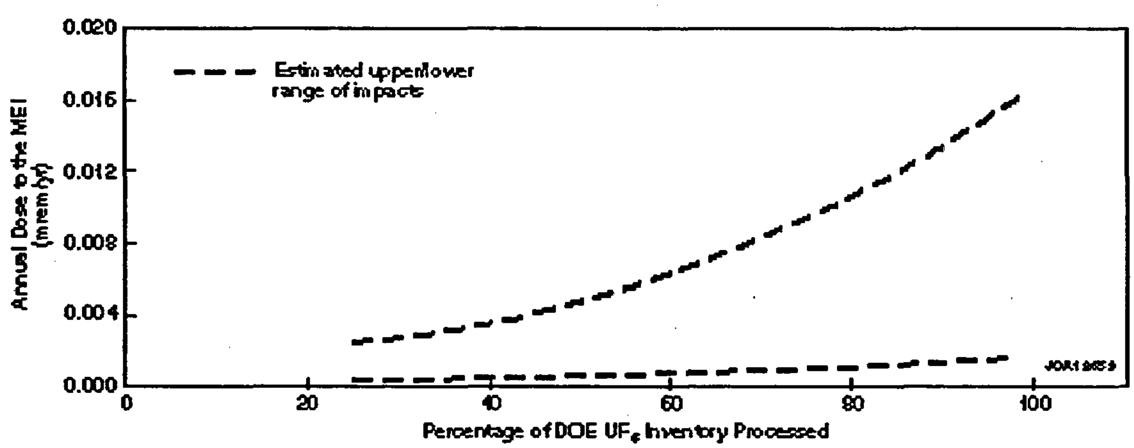

FIGURE K.60 Estimated Annual Dose to the Noninvolved Worker MEI from the Disposal of Grouted UO_2 (The upper and lower ranges reflect differences in representative dry and wet site characteristics.)

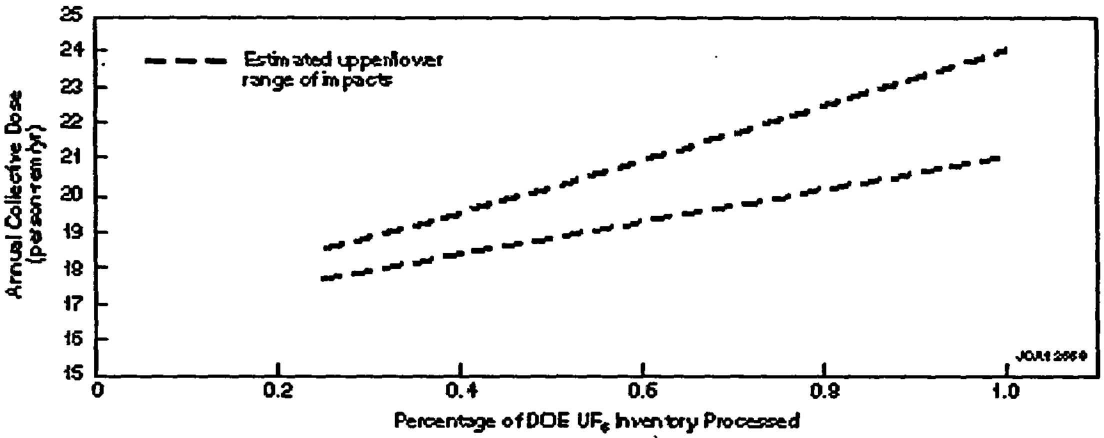

FIGURE K.61 Estimated Annual Collective Dose to Involved Workers from the Disposal of Grouted UO_2 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

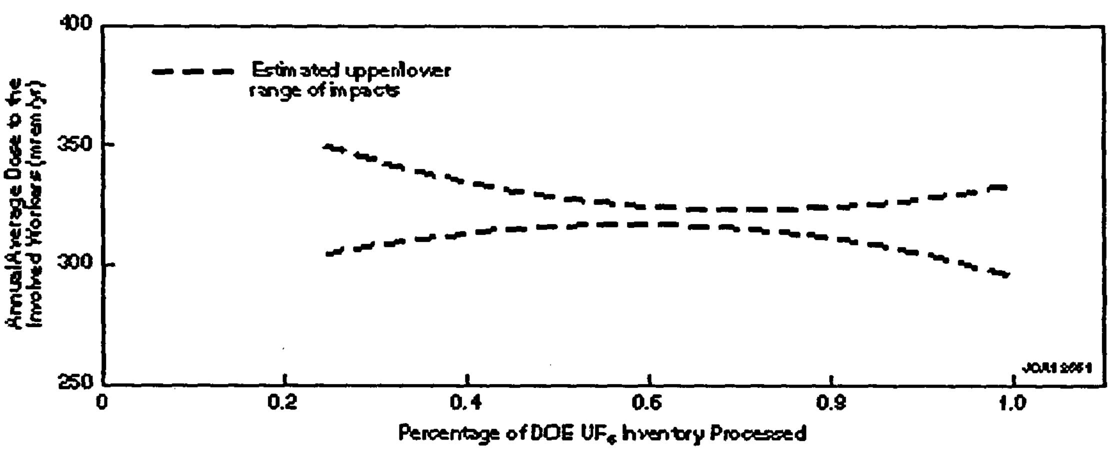

FIGURE K.62 Estimated Annual Average Individual Dose to Involved Workers from the Disposal of Grouted UO_2 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

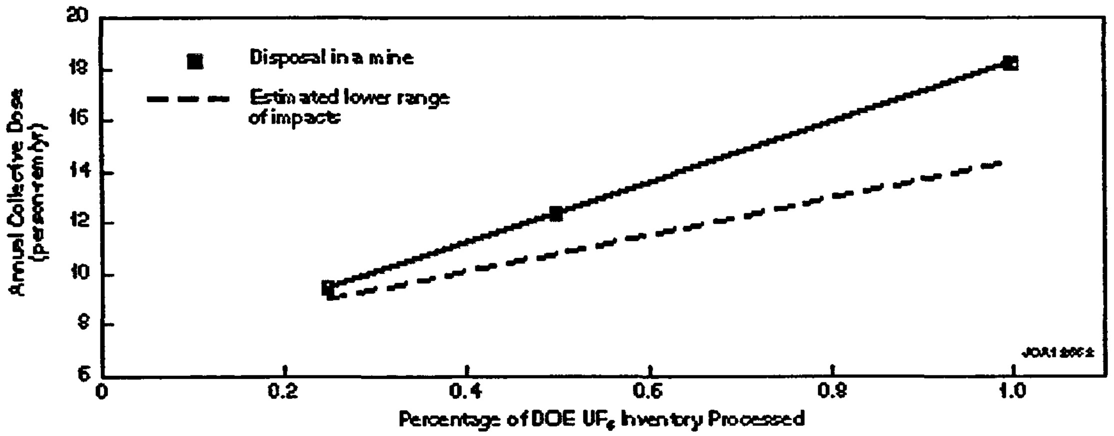

FIGURE K.63 Estimated Annual Collective Dose to Involved Workers from the Disposal of Ungrouted U_3O_8 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

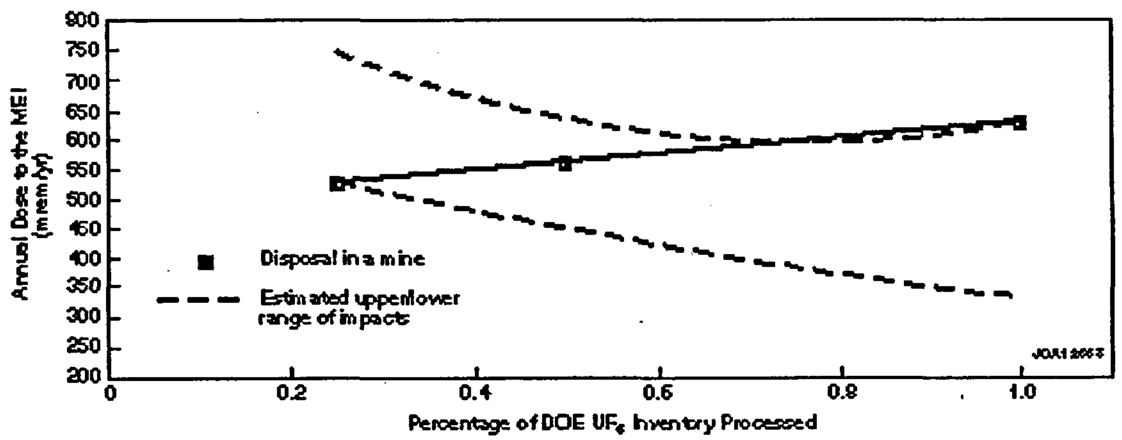

FIGURE K.64 Estimated Annual Average Individual Dose to Involved Workers from the Disposal of Ungrouted U_3O_8 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

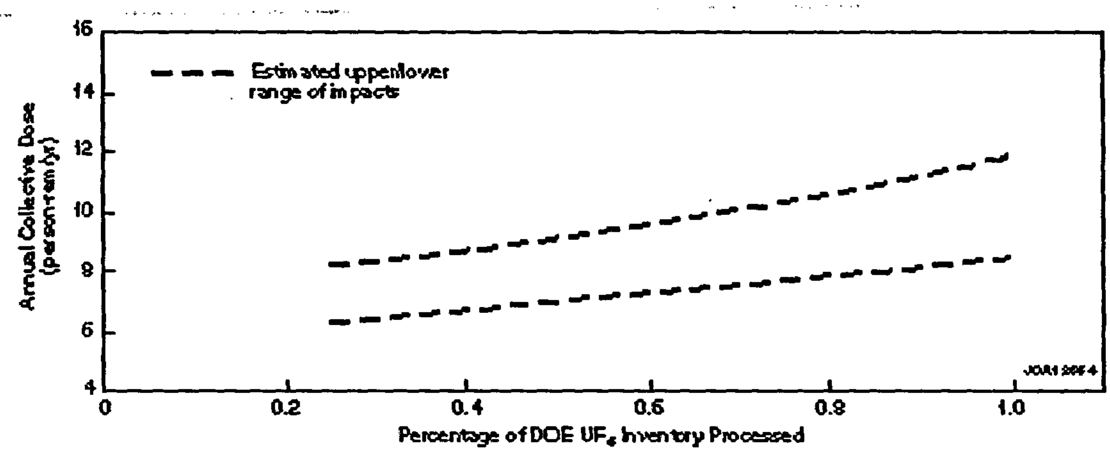

FIGURE K.65 Estimated Annual Collective Dose to Involved Workers from the Disposal of Ungrouted UO_2 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

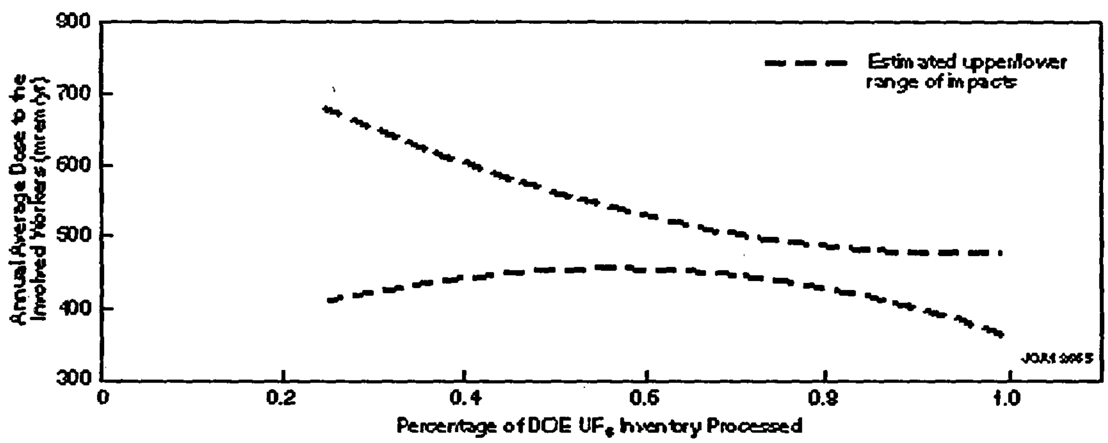

FIGURE K.66 Estimated Annual Average Individual Dose to Involved Workers from the Disposal of Ungrouted UO_2 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, and mine.)

In general, the results of the parametric analysis (as shown in Figures K.51 through K.66) indicate that the collective radiological impacts during the operational phase would decrease with the total quantity of depleted uranium disposed of. The impacts of the 25% and 50% cases would be smaller than those for the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than half of the impacts for the 100% case). Overall, radiation doses would be larger for the disposal of grouted waste compared with ungrouted waste because of the additional activities required and the small emissions resulting from the grouting process. In some cases, the average individual worker dose might increase or decrease as the throughput increased, primarily because the number of workers required would not increase at the same rate as the collective dose. The doses shown in the figures can be converted to the number (or risk) of LCFs by multiplying the doses (in rem or person-rem) by 0.0005 LCF/person-rem for members of the general public and 0.0004 LCF/person-rem for workers. Additional discussion of the significance of the estimated doses is provided in Appendix I.

K.5.1.1.2 Post-Closure Phase

At some time in the future after the closure of the disposal facility, potential impacts could occur to the public through the use of contaminated groundwater and from external radiation if the cover materials eroded away. In general, the complete erosion of the cover material, especially for a vault or mine, would not occur until thousands of years after the facility had been closed. Therefore, external radiation exposures would not be expected within the time frame considered (i.e., 1,000 years). Even if complete erosion occurred, the radiation exposure could be reduced by adding new cover material. Groundwater contamination would not be expected to occur until hundreds to thousands of years after the disposal facility had been closed. The estimated groundwater concentrations and associated uncertainty are discussed in Appendix I. For assessment purposes, the MEI was assumed to live at the edge of the disposal site and to use groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. The potential radiation doses from using contaminated groundwater were based on groundwater concentrations calculated in the groundwater analysis that is discussed in detail in Section K.5.4.2.

The results of the groundwater analysis for a representative dry location indicate that measurable groundwater contamination would not occur until over 10,000 years after failure of the disposal facility. Therefore, no radiation exposures of the public would be expected for thousands of years following disposal in a dry environment.

Potential radiation exposures of the general public would be much greater if the disposal site was located in a wet environment. The results of the analysis indicate that the radiation dose to an individual using contaminated groundwater could reach about 80 mrem/yr for the 25% case, 96 mrem/yr for the 50% case, and 110 mrem/yr for the 100% case (considering both grouted and ungrouted wastes and different disposal technologies); these impacts could occur 1,000 years after failure of the containers and engineering barriers if the soil properties were such that uranium was transported rapidly toward the groundwater (mobile situation). If the depleted uranium was classified as LLW, the radiation doses from using contaminated groundwater would exceed the dose limit of 25 mrem/yr specified in the *Code of Federal Regulations* (10 CFR Part 61) and DOE Order 5820.2a. However, radiation doses from contaminated groundwater could be reduced or eliminated by treating the water or by using an alternative source of water.

K.5.1.2 Chemical Impacts

K.5.1.2.1 Operational Phase

The estimated impacts from chemical exposures during the normal operation of full-scale (100%) disposal facilities are described in Appendix I, Section I.3.1.2. The results of the 100% case analyses for the operational phase indicated that noninvolved workers and members of the general public would receive essentially no exposures to chemicals for the disposal of ungrouted uranium material and very low exposures from disposal of grouted uranium material for all disposal facilities. No adverse health impacts would be expected for any of the disposal facilities considered. For the 100% cases, the calculated hazard indices were much less than 1 for all disposal options (a hazard index of greater than 1 indicates the potential for health impacts). For the parametric analysis of the 25% and 50% throughput cases, airborne emissions would be less than the 100% cases and extremely small (LLNL 1997a). Therefore, by comparison with the 100% case results, no adverse health impacts from chemical exposures would be expected for throughput rates between 25% and 100% for all disposal options.

K.5.1.2.2 Post-Closure Phase

As for radiological impacts, potential chemical impacts could occur to the general public at sometime in the future through use of contaminated groundwater. The potential chemical impacts to an MEI resulting from use of contaminated groundwater were determined on the basis of the same assumptions discussed in Section K.5.1.1 for radiological exposures. Chemical exposures were calculated for a time 1,000 years after the disposal facility was assumed to fail. The potential chemical impacts from using contaminated groundwater were based on the groundwater concentrations calculated in the groundwater analysis (see Section K.5.4.2).

Because of the low precipitation rate in a dry location, it would take more than 10,000 years for the uranium compounds to reach the groundwater after the first contact with infiltration water. Therefore, no chemical exposures would occur to an individual living next to the disposal site in a dry environment within 10,000 years.

Chemical exposures to the MEI could potentially be much greater if the disposal site was located in a wet environment. The concentrations of uranium in groundwater at 1,000 years after failure of the disposal facility would be such that potential adverse health impacts from chemical exposures could result to an individual using contaminated groundwater for all cases. Risks from chemical exposures were quantified on the basis of calculated hazard indices. Assuming that the soil properties were such that uranium compounds could be transported rapidly toward the groundwater following failure of the containers and engineering barriers (at 1,000 years), the maximum hazard indices were estimated to be greater than 1, indicating a potential for adverse health effects. The hazard indices were calculated to be 8 for the 25% case, 10 for the 50% case, and 11 for the 100% case. However, chemical exposures from contaminated groundwater could be reduced or eliminated by treating the water or by using an alternative source of water.

K.5.2 Human Health — Accident Conditions

K.5.2.1 Radiological Impacts

The estimated radiological impacts (radiation doses and LCFs) from potential accidents during operation of full-scale (100%) disposal facilities are presented in Appendix I, Section I.3.2.1. The analysis of the 100% cases considered a range of accidents in four frequency categories; results are presented only for those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

Based on the assessment of the 25% and 50% disposal cases, the radiological accident impacts associated with each of the parametric cases would be the same as those presented for the 100% case in Appendix I. The impacts would be identical because the bounding accidents producing the greatest consequences within each frequency category would be the same for the 100%, 50%, and 25% cases. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. However, as a result of the reduced throughput rates, the actual frequencies of some accidents related to handling operations (i.e., the "mishandle/drop of drum" accident) would decrease as the number of containers handled decreased. The resulting risk of these accidents would also decrease as their frequencies decreased. However, none of the accident frequencies would change enough to cause the accident to be considered in a different frequency category. Therefore, the overall impacts associated with the disposal options would be the same for all parametric cases.

K.5.2.2 Chemical Impacts

The estimated chemical impacts from potential accidents during full-scale (100%) operation of disposal as grouted or ungrouted UO_2 or U_3O_8 in shallow earthen structures, vaults, or a mine are presented in Appendix I, Section I.3.2.2. The analysis of 100% cases considered a range of accidents in four frequency categories; results are presented for only those accidents in each category that would have the greatest consequences (bounding accidents). Similar sets of accidents covering the same four frequency categories are defined in the engineering analysis report (LLNL 1997a) for the 25% and 50% throughput cases.

The bounding chemical accidents associated with the 25% and 50% throughput cases that would produce the greatest consequences would be the same as those presented for the 100% case. The impacts would be similar because the accidents within most frequency categories would be the same for the 100%, 50%, and 25% cases, and in those cases where these accidents were different, no adverse chemical impacts were estimated to occur. The bounding accidents would be the same because they would involve only a limited amount of material that would be at risk under accident conditions regardless of the facility size or throughput. However, some of the impacts for other accidents (nonbounding) considered for the 25% and 50% cases would be different from those for the 100% cases. In general, the impacts of the nonbounding accidents for the 50% and 25% cases would be less than those for the 100% cases because of the reduced throughput.

K.5.2.3 Physical Hazards

The estimated health impacts, such as on-the-job injuries and fatalities, from potential physical accidents during the construction and operation of full-scale (100%) disposal facilities are presented in Appendix I, Section I.3.2.3. For the 100% analysis, no on-the-job fatalities were estimated during construction and operation of a mine disposal facility (for ungrouted U_3O_8). The predicted number of on-the-job worker injuries for the 100% case is about 240. The impacts of the 25% and 50% cases would be smaller than those for the 100% case, although the decrease would not be proportional to the reduction in throughput (i.e., the impacts for the 50% case would be greater than 50% of the impacts for the 100% case).

The predicted number of on-the-job worker fatalities over the duration of disposal operations is less than 1, ranging from 0.4 for the 25% case to 0.53 for the 100% case (including construction and operations). The predicted number of on-the-job injuries (including construction and operations) ranges from 160 to 240. The number of injuries is shown as a function of throughput in Figure K.67.

K.5.3 Air Quality

The estimated impacts on air quality during construction and operation of full-scale (100%) disposal facilities are presented in detail in Appendix I, Section I.3.3. All of the pollutant concentrations produced by the 100% capacity version of the disposal facilities would be below their respective air quality standards. The annual average concentrations of NO_x might be as high as one-third of the air quality standards during operation of vault disposal facilities for grouted U_3O_8 in a wet environmental setting. During operations, all pollutant concentrations would be much less than the corresponding standards.

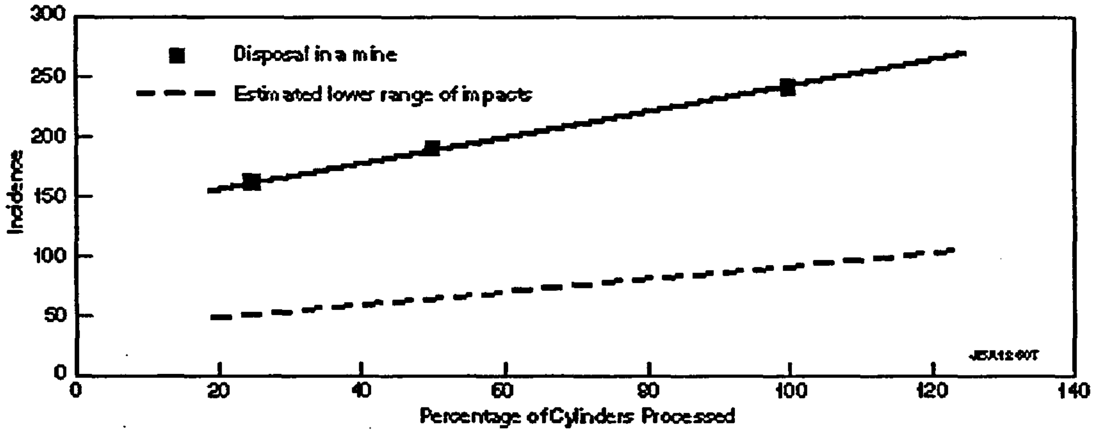

FIGURE K.67 Estimated Number of On-the-Job Injuries (for entire construction and operational periods) from the Disposal of Ungrouted U_3O_8 (The ranges reflect differences in disposal technologies, i.e., shallow earthen structures, vaults, or mine.)

The air quality impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% case. During construction, short-term impacts for the parametric cases would be less than those for the 100% case, and impacts during operations would also be less. Annual pollutant concentrations from construction of 50% and 25% capacity disposal facilities would be about 0.7 and 0.5 times as large as the full-capacity facility, respectively. For all the other disposal options, criteria pollutant levels would be lower percentages of their respective standards during both construction and operations.

K.5.4 Water and Soil

K.5.4.1 Surface Water

The estimated impacts on surface water during construction, operation, and potential accidents for full-scale (100%) disposal facilities are discussed in Appendix I, Section I.3.4. The actual impacts to surface water would depend on the ultimate site selected for disposal. However, for the generic sites considered in the PEIS, the impacts to surface water from the 100% case were found to be negligible for all disposal options for both the operational and post-closure phases. The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% case, and thus would also be negligible.

K.5.4.2 Groundwater

The estimated impacts on groundwater during construction, operation, and potential accidents for full-scale (100%) disposal facilities are presented in detail in Appendix I, Section I.3.4. The actual impacts to groundwater would depend on the ultimate site selected for disposal. However, during the operational phase, which would include construction and disposal activities, negligible impacts to groundwater would be expected. As described in Appendix I, the impacts to groundwater from the 100% case were expected to be negligible for the operational phase of all disposal options. The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were found to be less than those for the 100% case, and thus would also be negligible.

Impacts to groundwater during the post-closure phase are discussed in Section I.4.2. Groundwater impacts during the post-closure phase would be limited to changes in quality caused by contamination migrating from the disposal facility hundreds to thousands of years in the future after failure of the engineered barriers. There would be no impacts to effective recharge, depth to groundwater, or flow direction once the facility was constructed.

Disposal facility failure would generally occur hundreds to thousands of years in the future (assuming no sustained effort to maintain the facility). This failure would be caused by natural degradation of the disposal structures over time, primarily from physical processes such as the intrusion of water. Following failure, the release of uranium from the facility would occur very slowly as water moved through the disposed material. The amount of groundwater contamination, as well as the length of time it would take for the groundwater to become contaminated, would depend on the integrity of the drums and the engineering barriers, as well as the site-specific properties of the soil surrounding the disposal facility. Without more precise information concerning the expected lifetimes of the containers and engineering barriers in the specific disposal facility environment, as well as site-specific soil and hydrological properties, the groundwater concentrations estimated for the analysis presented in this appendix using generic assumptions are subject to a large degree of uncertainty. Nevertheless, if no remedial actions were taken, once the release of uranium from the disposal facility began, it could last for millions of years for all three cases (25%, 50%, and 100%).

If the disposal site were located in a dry environment, all of the resulting uranium concentrations in groundwater would be essentially zero for at least 1,000 years in the future (Tomasko 1997) for disposal of 25%, 50%, and 100% of the uranium material. In a wet climate, however, the uranium concentrations in the groundwater beneath a mined facility for ungrouted U_3O_8 would range from about 260 pCi/L (1,000 μg/L) for the 25% capacity case to 350 pCi/L (1,400 μg/L) for 100% capacity if the soil properties were such that the uranium moved rapidly through the soil (a retardation factor of 5). These uranium concentrations would exceed the U.S. Environmental Protection Agency (EPA) proposed maximum contaminant level of 20 μg/L (EPA 1996) used as a guideline in this PEIS. If the uranium were less mobile in the soil surrounding the disposal facility (retardation coefficient of 50), uranium concentrations in the groundwater beneath the facility after 1,000 years for disposal of 25%, 50%, and 100% would be less than 20 μg/L. However, the concentrations would increase with time, ultimately approaching the concentrations that would occur under the mobile situation and exceeding 20 μg/L.

Post-closure impacts to groundwater quality resulting from disposal in an underground mine could be reduced by decreasing the size of the facility in a direction parallel to the direction of groundwater flow, thereby increasing dilution (Tomasko 1997).

K.5.4.3 Soil

The estimated impacts to soil during construction, operation, and potential accidents for full-scale (100%) disposal facilities are presented in Appendix I, Section I.3.4. The potential impacts evaluated included changes in topography (land elevation), permeability (ability to let water enter the ground), quality, and erosion potential for a dry and wet location. Although impacts were evaluated for dry and wet conditions, the impacts would be essentially the same for both locations.

As discussed in Appendix I, the impacts to soil from the 100% cases were found to have potentially moderate to large, but temporary, impacts for the disposal options. These impacts would result from material excavated during disposal facility construction that would be left on-site. For example, construction of a mine for ungrouted U_3O_8 disposal would require excavating about 1.2 million yd^3 (920,000 m^3) of consolidated material. In the short term, this amount of material would cause changes in site topography. In the long term, contouring and reseeding would return soil conditions to their former state, and the impacts would be minor. The impacts calculated for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), were also found to have potentially large, but temporary, impacts on soil, similar to the 100% cases. In the long term, impacts on soil would be minor for all disposal options.

K.5.5 Socioeconomics

The socioeconomic impacts of ungrouted U_3O_8 mine disposal facilities for the 50% and 25% parametric cases would be less than the impacts of the base-case facility sizes. Cost information was not available in sufficient detail to allow an analysis of impacts using the same methodology that was used for the base cases. The impacts of parametric cases were therefore assessed qualitatively, based on the assumption that changes in the cost of equipment, materials, and labor would be proportional to changes in total life-cycle cost. Compared with base-case facility sizes, smaller U_3O_8 mine disposal facilities would create less direct employment and income at the site.

K.5.6 Ecology

Site preparation for the construction of a facility for the disposal of ungrouted U_3O_8 in a mine would result in the disturbance of biotic communities, including the permanent replacement of habitat with structures and paved areas. Existing vegetation would be destroyed during land-clearing activities. Wildlife would be disturbed by land clearing, noise, and human presence.

This disposal option would result in elevation of the soil surface by approximately 2.8 to 4.1 ft (0.85 to 1.2 m) and a reduction in soil permeability. The excavated material would primarily consist of rock removed from the drifts and ramps. The consequent decrease in surface soil moisture would make reestablishment of vegetation difficult and delay the establishment of native plant communities. Construction of a disposal facility for ungrouted U_3O_8 in a mine would result in a large adverse impact to existing vegetation and wildlife.

Impacts to wetlands and state and federally protected species due to facility construction would depend on facility location. Avoidance of wetland areas would be included during facility planning. Site-specific surveys for protected species would be conducted prior to finalization of facility siting plans.

Impacts to air, surface water, groundwater, and soil quality during construction are expected to be negligible for the 25%, 50%, and 100% cases (Sections K.5.3 and K.5.4). Resulting construction-derived impacts to ecological resources would also be expected to be negligible. Impacts to ecological resources from air and water emissions would also be negligible during the operational phase of the disposal options.

During the post-closure phase, failure of facility integrity could result in contamination of groundwater (see Section K.5.4.2). Groundwater could discharge to the surface (such as in wetland areas) near the facility, thus exposing biota to contaminants. Groundwater concentrations of uranium calculated for 1,000 years after failure of a mined facility for ungrouted U_3O_8 would range from about 260 to 350 pCi/L for the 25% and 100% cases, respectively. Similarly, groundwater concentrations for a mined facility for grouted U_3O_8 would range from about 310 to 425 pCi/L for the 25% and 100% cases, respectively. Adverse impacts to aquatic biota could result from exposure to soluble uranium compounds within this concentration range. Resulting dose rates to maximally exposed organisms would be less than 2% of the dose limit of 1 rad/d, for aquatic organisms, as specified in DOE Order 5400.5.

K.5.7 Waste Management

The estimated impacts from waste management operations from the construction and operation of full-scale (100%) disposal facilities are presented in detail in Appendix I, Section I.3.7. The impacts on national waste management operations from construction of disposal facilities were found to be negligible for the 100% throughput case. The impacts that would result from construction for the 25% and 50% parametric cases, based on information provided in the engineering analysis report (LLNL 1997a), would be less than those for the 100% case, and thus would also be negligible.

Operation of a disposal facility would generate radioactive, hazardous, and nonhazardous wastes (Section I.3.7). All of the secondary wastes listed would have a negligible impact on waste management capacities across the DOE complex. However, the product waste would represent a significant volume when compared with the complexwide total of LLW for disposal. Disposal of 100% of the depleted uranium inventory could represent from 1.1 to 7.3% of the total DOE LLW generated over roughly the same time period. Overall, the waste input resulting from the normal operation of the U_3O_8 disposal facility would have a negligible to low impact on DOE's complexwide waste management activities.

The parametric analysis of operational waste loads was conducted for throughput values of 25%, 50%, and 100% (Table K.5). Some of these analyses showed nonlinear effects, but the estimated impacts would be very small. The volume of product waste was shown to be linear with throughput. Thus, it was assumed that a linear interpolation could be used to estimate waste loads for throughput values other than 25%, 50%, and 100%.

K.5.8 Resource Requirements

The estimated impacts from resource requirements during construction and operation of full-scale (100%) disposal facilities are presented in detail in Appendix I, Section I.3.8. The impacts on resources, except for electrical consumption for a mine disposal facility, would be expected to

TABLE K.5 Wastes Generated during Facility Operations from the Disposal of Ungrouted U_3O_8

	Annual Waste Generated for Three Throughput Cases		
Waste Type	100%	50%	25%
Waste (m^3/yr)			
Solid LLW	81	57	40
Mixed liquid LLW	0.31	0.22	0.15
Nonhazardous waste (million L/yr)			
Solids	0.64	0.45	0.32
Wastewater	0.92	0.68	0.48
Product waste volume (m^3/yr)			
Ungrouted U_3O_8	7,440	3,720	1,860

be small for the 100% capacity case. Resource requirements for the 25% and 50% parametric cases considered would be less than those for the 100% case (LLNL 1997a).

Construction and operation of the disposal facilities would consume irretrievable amounts of electricity, fuel, concrete, steel and other metals, water, and miscellaneous chemicals. The total quantities of commonly used materials would not be expected to be significant. However, for a mine disposal facility, significant quantities of electrical energy would be required during construction (up to 1,100 MW-yr, orders of magnitude greater than that required for other disposal facility types) because the majority of the construction equipment used in the underground portion would be powered by electricity to avoid polluting the air in the underground work area. Similarly, compared with the other options, a relatively higher annual amount of electricity would be needed during underground operations. No strategic and critical materials would be expected to be consumed during construction or operation of the facilities. The disposal facility operations requirements would generally not be resource-intensive, and the resources required are not considered rare or unique. Furthermore, committing any of these resources (except for electrical consumption) would not be expected to cause a negative impact on the availability of these resources within local areas or nationally for the 100%, 50%, and 25% cases. The magnitude of impact of the high electrical requirement for a mine disposal facility on local energy resource usage would be dependent on the extent of existing site infrastructure.

K.5.9 Land Use

Potential moderate to large impacts from the construction and operation of a mined disposal facility would be expected from on-site disposal of excavated material. Potential traffic volume impacts would be associated with the construction labor force. Site preparation for the construction of a facility for the disposal of ungrouted U_3O_8 in a mine for 25%, 50%, and 100% of the depleted UF_6 inventory would require the disturbance of approximately 97, 165, and 232 acres (39, 66, and 93 ha), respectively. On-site topographical modifications associated with disposition of the excavated material could potentially affect future on-site land use, although such impacts would be small. Land use impacts from shallow earthen structure and vault options would range from negligible to moderate.

Impacts to land use outside the boundaries of a disposal facility would consist of temporary traffic impacts associated with project construction. The actual impacts would depend on the specific site chosen.

K.5.10 Other Impacts Considered But Not Analyzed in Detail

There are other impacts that can potentially occur if the disposal options considered in this PEIS are implemented. They include impacts to cultural resources and environmental justice, as well as to aesthetics (e.g., visual environment), recreational resources, and noise levels, and impacts associated with decontamination and decommissioning of surface disposal facilities. These impacts, although considered, were not analyzed in detail for one or both of the following reasons:

- The impacts could not be determined at the programmatic level without consideration of specific sites. These impacts would be more appropriately addressed in the second-tier NEPA documentation when specific sites are considered.

- Consideration of the impacts would not contribute to differentiation among the alternatives; therefore, it would not affect the decisions to be made in the Record of Decision that will be issued following publication of this PEIS.

K.6 TRANSPORTATION

The estimated environmental impacts were presented in Appendix J for transportation of materials associated with the 100% cases considered for the depleted uranium inventory options. Because the locations of the various facilities are not determined, impacts for three shipment distances (250, 1,000, and 5,000 km) were presented to give the reader a basis for understanding the ramifications of shipment distance on the impacts. In this appendix, all transportation impacts are presented for a single shipment distance of 1,000 km because the objective here is the comparison among the three cases of throughput (25%, 50%, and 100%) associated with the depleted uranium.

The transportation impacts are presented in the form of line graphs in terms of risk (estimated fatalities) as a function of the number of total shipments over the 20-year life of the project. Each graph pertains to a single type of shipment either by truck or rail mode. As in Appendix J, estimated fatality risks from radiological (routine and accident), chemical (accident), and vehicle (routine and accident) causes are presented in each graph. The 25%, 50%, and 100% throughput cases are denoted with vertical lines on each graph.

K.6.1 Conversion Options

The conversion of the depleted UF_6 to an oxide or a metal form might require shipment of the depleted uranium to an off-site facility. Impacts for the 100% case are presented in Appendix J, Section J.3.4. Figures K.68 and K.69 present the results for shipping the depleted uranium cylinders either by truck or rail, respectively, for the three parametric cases. The 100% case risks for cylinder shipment are presented in Tables J.5 and J.6 in Section J.3.4.1. The impacts from routine external radiation if overcontainers were to be used are also presented. The radiological and chemical risks from accidents are not presented because these risks would be at least 100 times less than the other estimated risks.

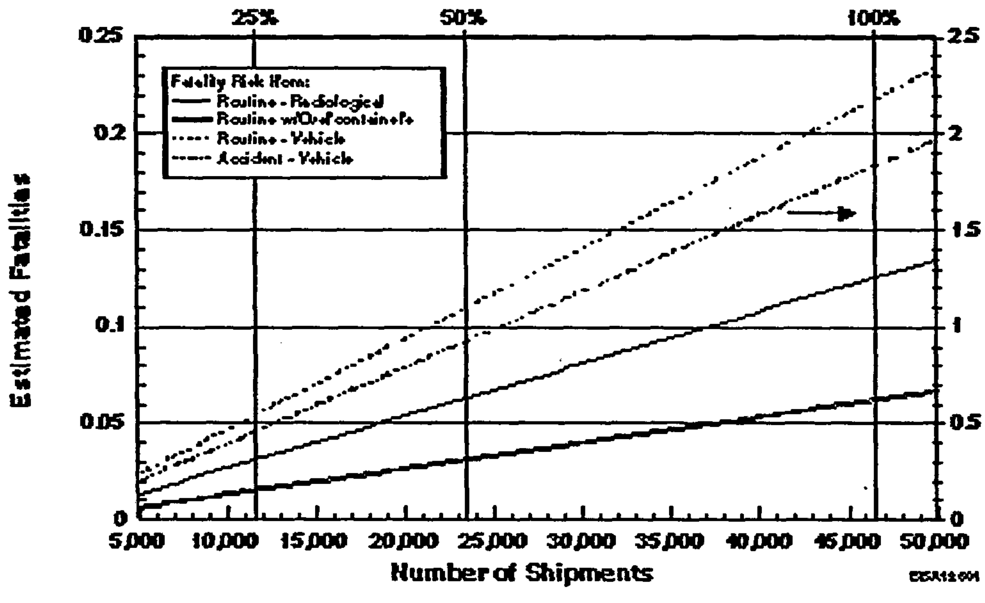

FIGURE K.68 Estimated Truck Transportation Risks for Depleted UF_6 Cylinders

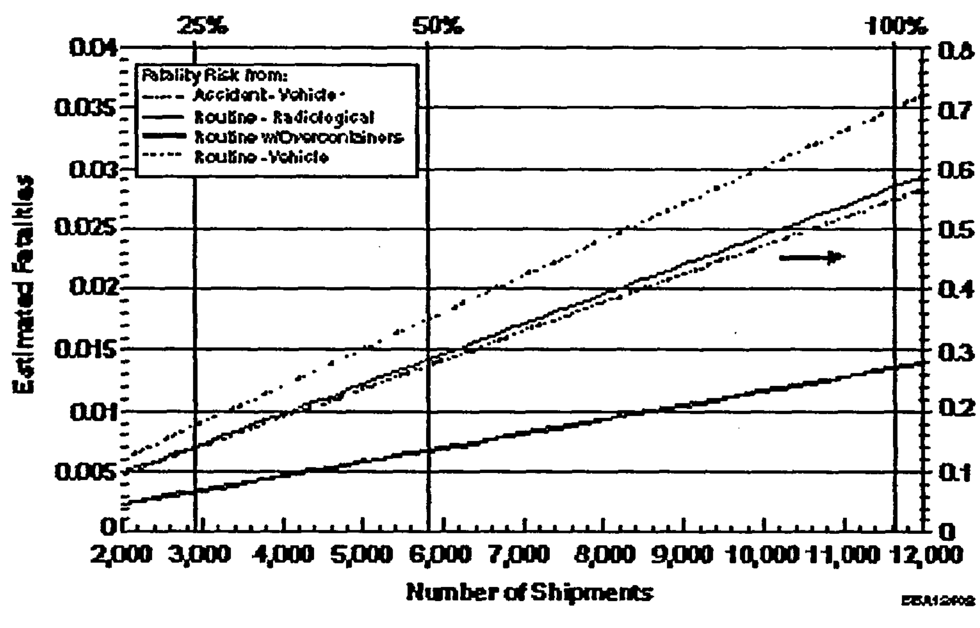

FIGURE K.69 Estimated Rail Transportation Risks for Depleted UF_6 Cylinders

Conversion of the depleted UF_6 to an oxide or uranium metal would involve transportation of input materials and output waste forms, as discussed in Appendix J, Section J.3.4. Ammonia might be used as an input material for oxide and metal conversion; Figure K.70 presents the chemical and vehicle risks from transportation of ammonia for shipment by rail for UO_2 or metal conversion. Anhydrous HF is a common product of the three conversion technologies studied for the parametric analysis. The two oxide technologies would produce about the same amount of HF for the same amount of depleted UF_6 input, an amount that is about three times the amount of HF produced in the conversion to metal. Figure K.71 presents the parametric risks for HF transport. The conversion-to-metal process would produce a large quantity of nonhazardous MgF_2 as another by-product. The vehicle-related parametric risks for transport of MgF_2 by truck and rail are shown in Figures K.72 and K.73, respectively.

Both LLW and low-level mixed waste (LLMW) would be produced at a conversion facility and would require transport for disposal, as discussed in Appendix J, Section J.3.4.2. The number of shipments required for LLMW disposal in all three options is not expected to change with the throughput case (25%, 50%, or 100%) because a minimal amount would be generated by the conversion process. The estimated transportation risks for the LLW generated at the three different conversion facilities shipped to a disposal site are presented in Figures K.74 through K.76.

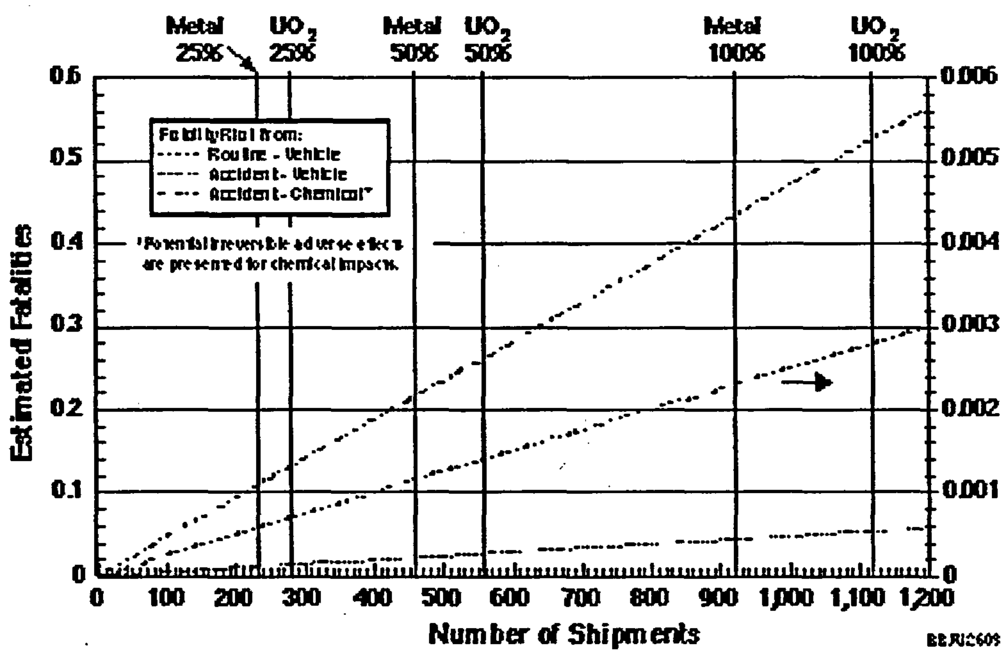

FIGURE K.70 Estimated Rail Transportation Risks for the Ammonia Used in the Conversion of Depleted UF_6 to UO_2 or Uranium Metal

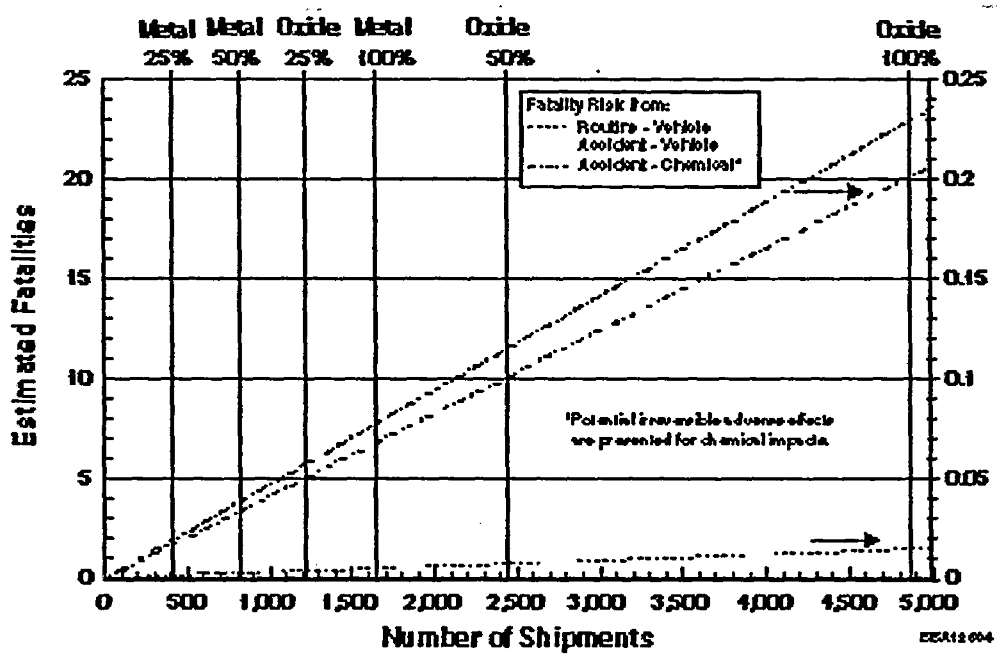

FIGURE K.71 Estimated Rail Transportation Risks for the HF Produced in the Conversion of Depleted UF_6 to U_3O_8, UO_2, or Uranium Metal

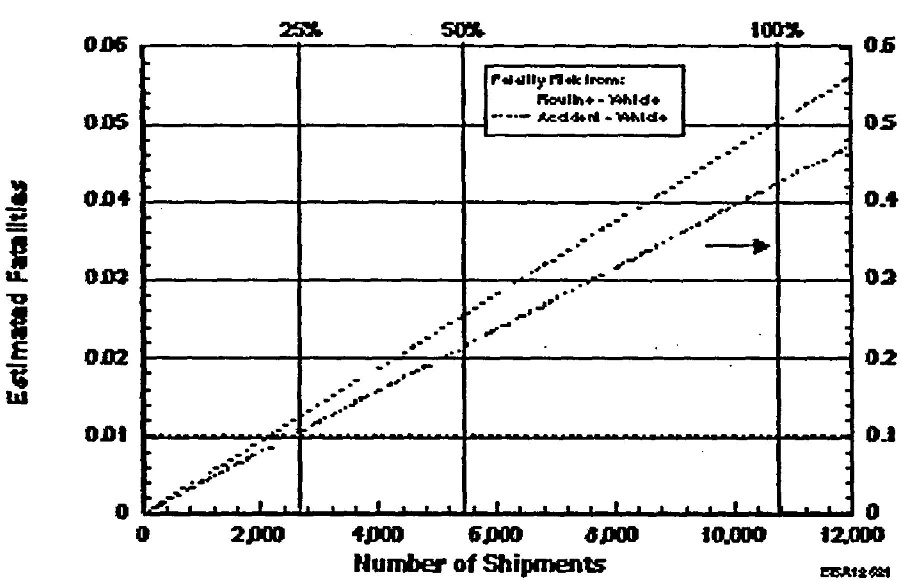

FIGURE K.72 Estimated Truck Transportation Fatality Risks for the MgF_2 Generated in the Conversion of Depleted UF_6 to Uranium Metal

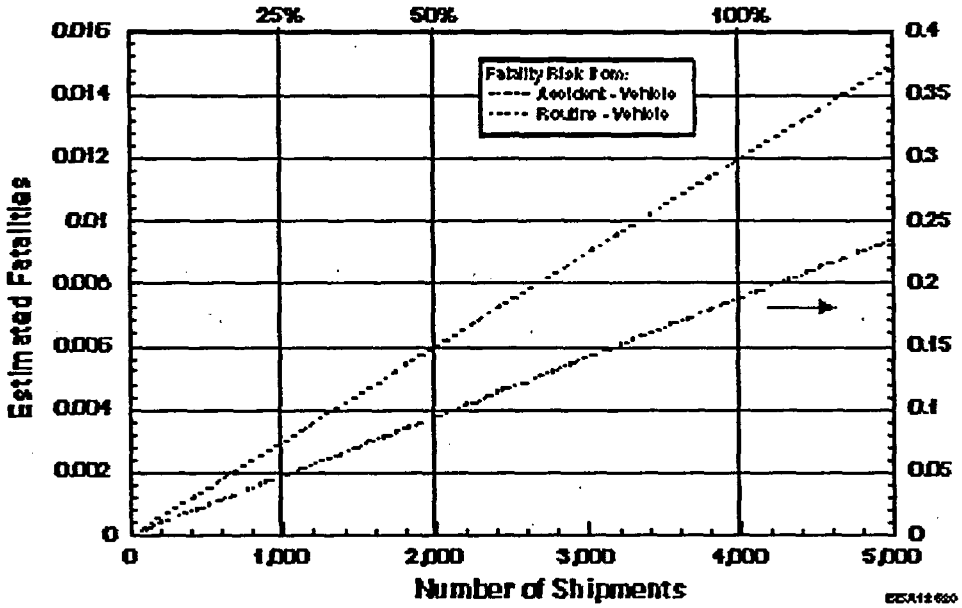

FIGURE K.73 Estimated Rail Transportation Fatality Risks for the MgF_2 Generated in the Conversion of Depleted UF_6 to Uranium Metal

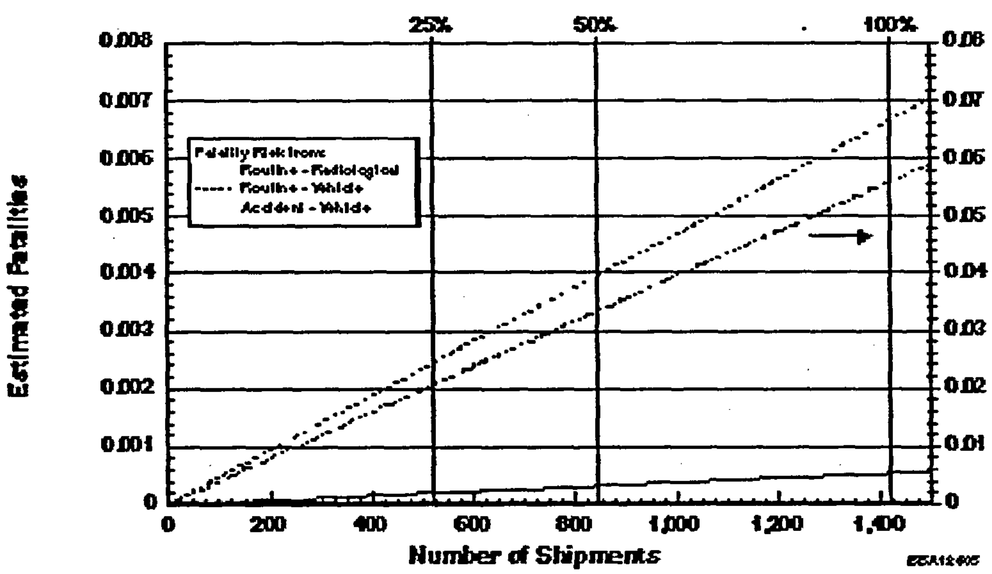

FIGURE K.74 Estimated Truck Transportation Risks for the LLW Generated in the Conversion of Depleted UF_6 to U_3O_8

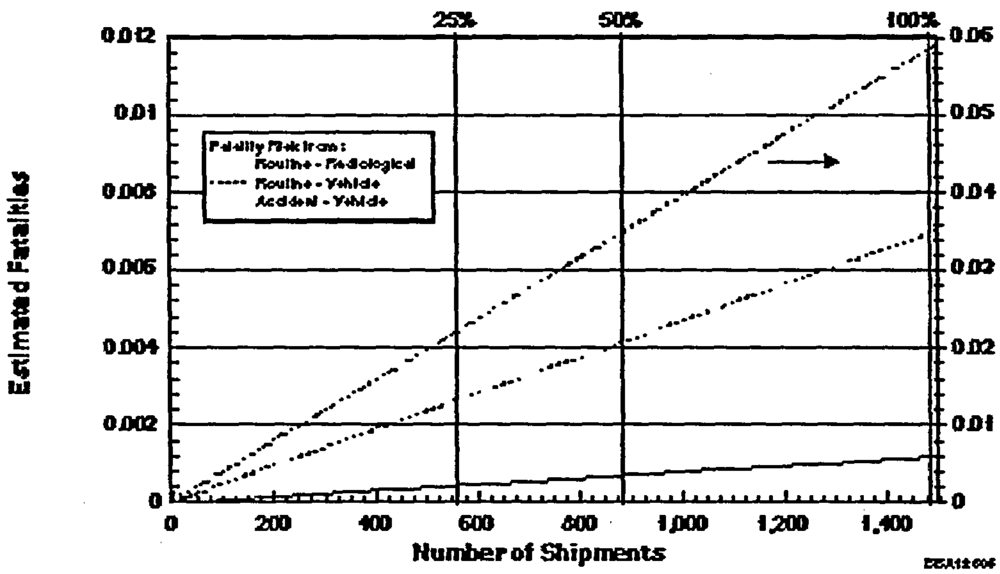

FIGURE K.75 Estimated Truck Transportation Risks for the LLW Generated in the Conversion of Depleted UF_6 to UO_2

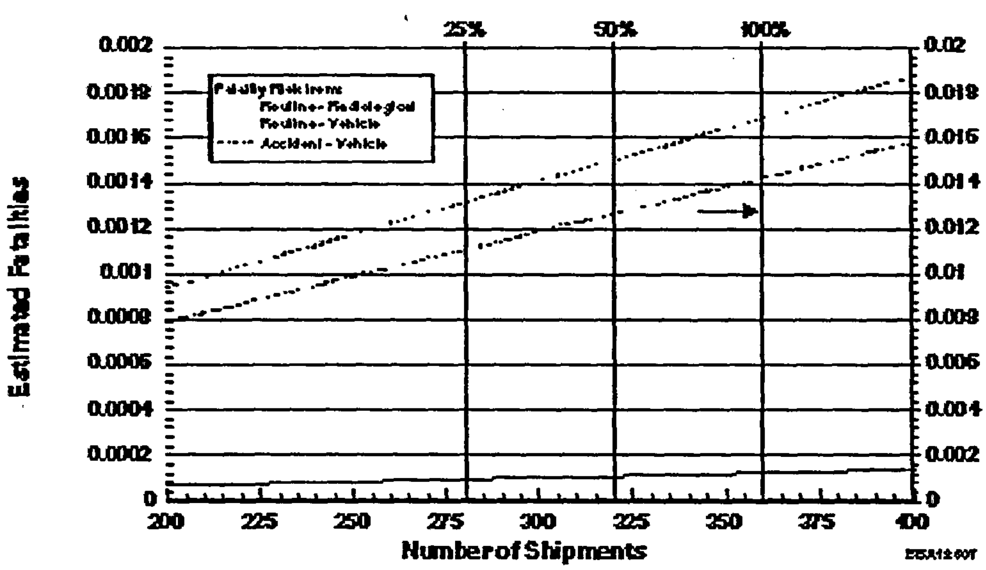

FIGURE K.76 Estimated Truck Transportation Risks for the LLW Generated in the Conversion of Depleted UF_6 to Uranium Metal

Radiological and chemical risks from accidents are not presented because they would be at least 100 times less than the other estimated risks.

Parametric transportation risks for the shipment of U_3O_8 are provided in Section K.6.4 under the U_3O_8 disposal option. Parametric transportation risks for the UO_2 conversion product are discussed in Section K.6.2 under the UO_2 long-term storage option, and the risks for the metal conversion product are discussed in Section K.6.3 for the manufacture and use option.

Each conversion option would require cleaning of the empty depleted UF_6 cylinders at the cylinder treatment facility, as discussed in Appendix J, Section J.3.4.3. The parametric transportation risks for the resulting LLW and U_3O_8 are presented in Figures K.77 and K.78, respectively. For the LLW shipments, the radiological and chemical risks are not presented because they are at least 100 times less than the vehicle emission risks, as shown in Appendix J, Section J.3.4.3. The number of shipments required for the LLMW generated at the cylinder treatment facility is not expected to change appreciably with the throughput case (25%, 50%, or 100%) because a minimal amount would be generated by the cleaning process.

K.6.2 Long-Term Storage Options

Storage as UF_6 in buildings assumes transportation of the depleted UF_6 cylinders to a storage site. Parametric risks from transportation of the depleted UF_6 cylinders is discussed in Section K.6.1. A very small amount of LLW and LLMW would be generated from occasional cylinder failure during the surveillance phase of this option. The type of waste generated would be similar to that generated at the cylinder treatment facility and would have similar single shipment risks. As discussed in Appendix J, Section J.3.5, less than one shipment per year is expected for the 100% case, with slightly fewer shipments necessary for the 50% and 25% cases.

Transportation of UO_2 from a conversion facility might be required for long-term storage as oxide, as discussed in Appendix J, Section J.3.5. Figures K.79 and K.80 present the results for shipping the UO_2 conversion product exclusively by truck or rail, respectively, for the three parametric cases. The chemical accident risks for UO_2 are not presented because they would be more than 100 times less than the routine radiological risks shown in Tables J.11 and J.12 for the 100% case.

K.6.3 Manufacture and Use Options

K.6.3.1 Use as Uranium Oxide

The estimated transportation risks for shipment of all the UO_2 from a conversion facility to a manufacturing site for uranium oxide cask production are presented in Appendix J,

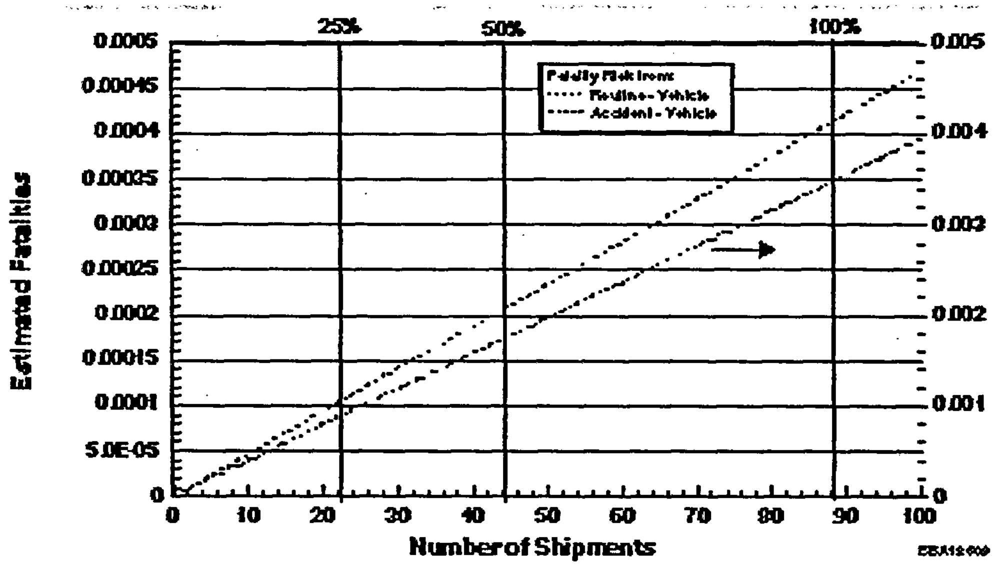

FIGURE K.77 Estimated Truck Transportation Risks for the LLW Generated at the Cylinder Treatment Facility

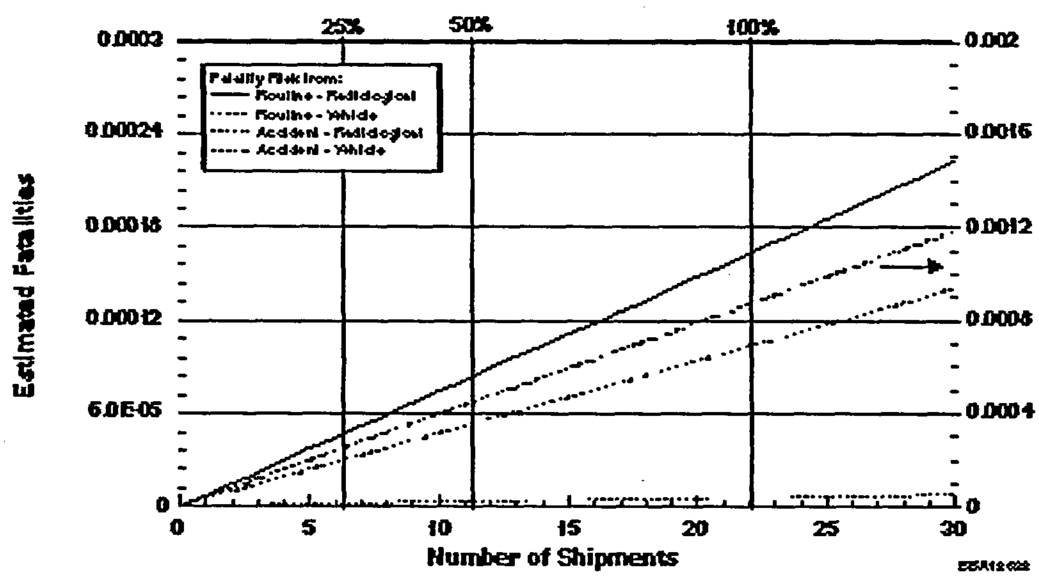

FIGURE K.78 Estimated Truck Transportation Risks for the U_3O_8 Generated at the Cylinder Treatment Facility

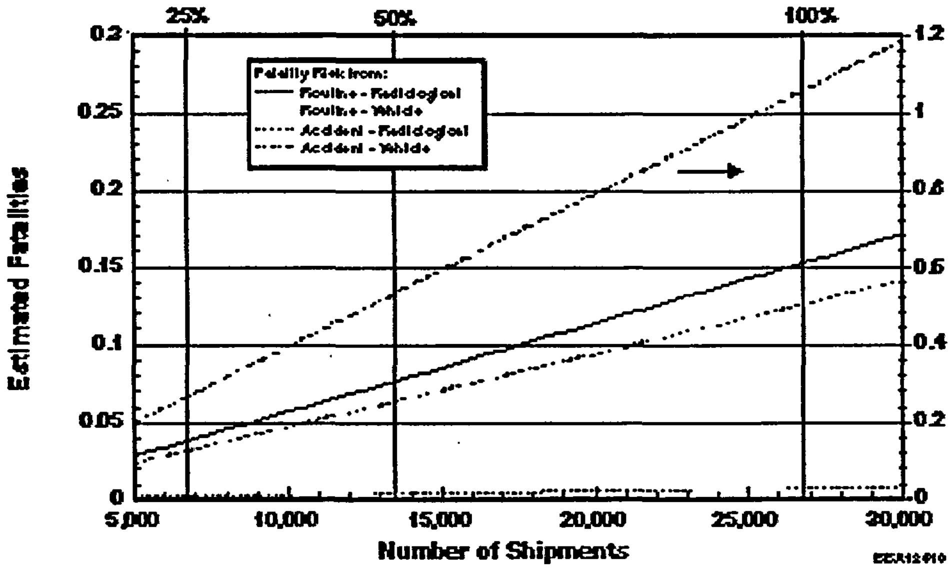

FIGURE K.79 Estimated Truck Transportation Risks for UO_2 Shipped from the Conversion Facility to Long-Term Storage or Oxide Cask Manufacture

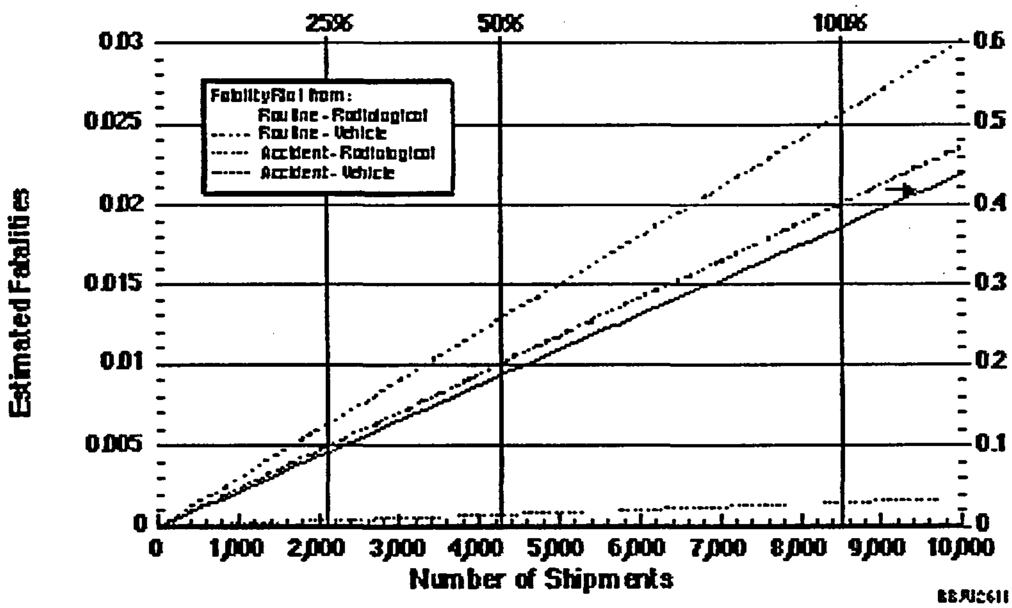

FIGURE K.80 Estimated Rail Transportation Risks for UO_2 Shipped from the Conversion Facility to Long-Term Storage or Oxide Cask Manufacture

Section J.3.6.1. The parametric risks for UO_2 are shown in Figures K.79 and K.80 for shipment by truck and rail, respectively.

Uranium oxide cask production would result in the generation of some LLW and LLMW, as discussed in Appendix J, Section J.3.6. The parametric results for the shipment of the LLW by truck to a disposal site are shown in Figure K.81. Radiological and chemical accident risks are not presented because they are more than 1 million times less than the other results shown in Tables J.15 and J.16 for the 100% case. The number of shipments required for LLMW disposal is not expected to change appreciably with the throughput case (25%, 50%, or 100%) because a minimal amount would be generated by the manufacturing process.

The transportation risks for shipment of the uranium oxide cask by rail from the manufacturing facility to an end-user are given in Appendix J, Section J.3.6.1. Figure K.82 shows the risks associated with rail shipments of the uranium oxide casks for the three parametric cases. Radiological and chemical accident risks are not presented because they are approximately 1 million times less than the other results shown in Tables J.15 and J.16 for the 100% case.

K.6.3.2 Use as Uranium Metal

The estimated transportation risks for shipment of all of the uranium metal from a conversion facility to a manufacturing site for metal cask production are presented in Appendix J, Section J.3.6.2. The parametric risks for the metal shipments are presented in Figures K.83 and K.84 for shipment by truck or rail, respectively. Radiological and chemical accident risks are not presented because they would be more than 1 million times less than the other results shown in Tables J.15 and J.16 for the 100% case.

The metal cask production would result in the generation of some LLW and LLMW, as discussed in Appendix J, Section J.3.6.2. The parametric results for the shipment of the LLW by truck to a disposal site are shown in Figure K.85. Radiological and chemical accident risks are not presented because they would be more than 100 times less than the other risks shown. The number of shipments required for LLMW disposal is not expected to change appreciably with the throughput case (25%, 50%, or 100%) because a minimal amount is generated by the manufacturing process.

The transportation risks for shipment of the metal cask by rail from the manufacturing facility to an end-user are given in Appendix J, Section J.3.6.2. Figure K.86 shows the risks associated with rail shipment of the metal casks for the three parametric cases. Routine radiological risks are not presented because these risks would be about 100 times less than the risks for the 100% case; radiological and chemical accident risks are also not presented because they would be approximately 100 million times less than the other risks for the 100% case, as shown in Tables J.15 and J.16.

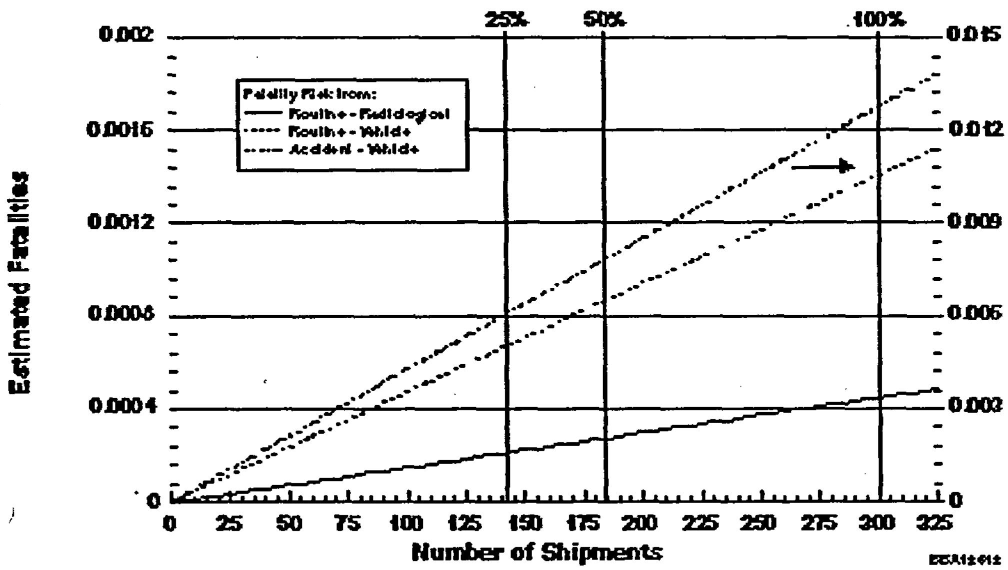

FIGURE K.81 Estimated Truck Transportation Risks for Shipment of LLW from the Oxide Cask Manufacturing Facility to a Disposal Site

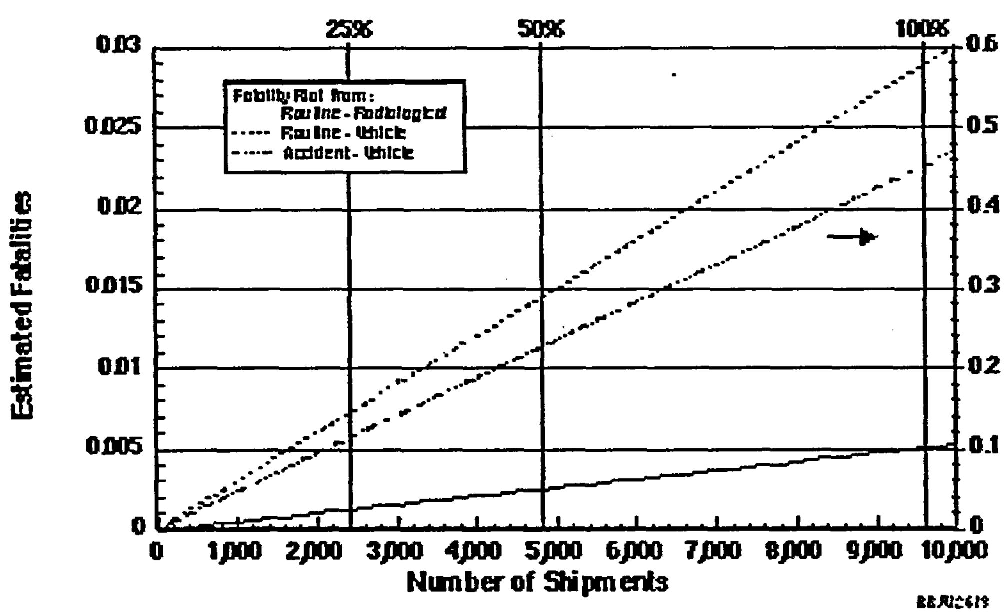

FIGURE K.82 Estimated Rail Transportation Risks for Shipment of Oxide Casks from the Cask Manufacturing Facility to an End-User Site

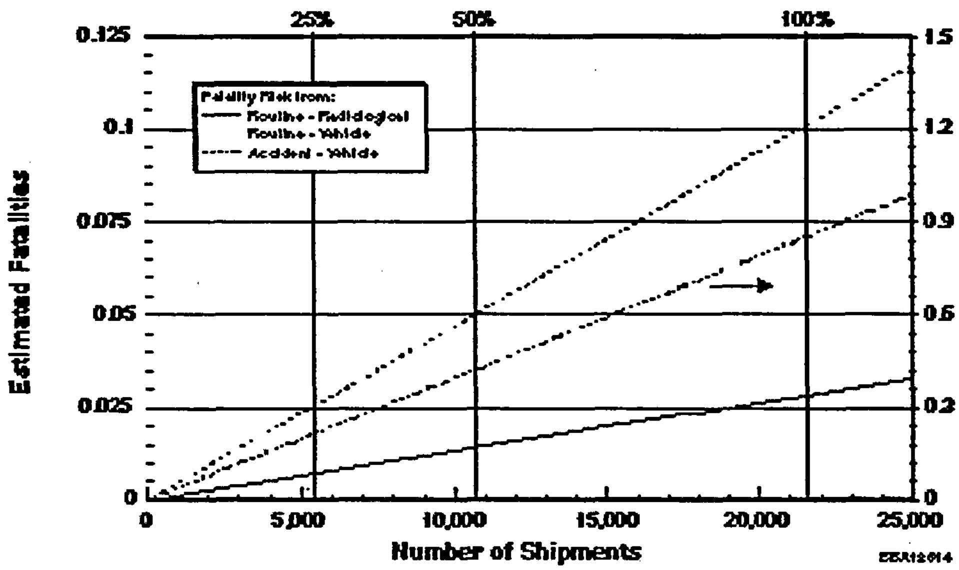

FIGURE K.83 Estimated Truck Transportation Risks for Uranium Metal Shipped from the Conversion Facility to Metal Cask Manufacture

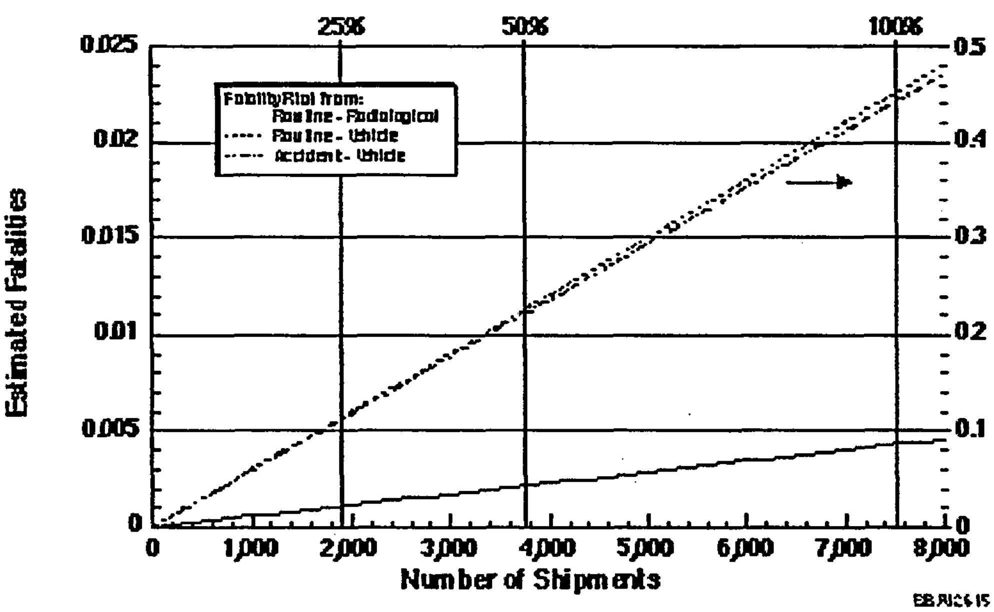

FIGURE K.84 Estimated Rail Transportation Risks for Uranium Metal Shipped from the Conversion Facility to Metal Cask Manufacture

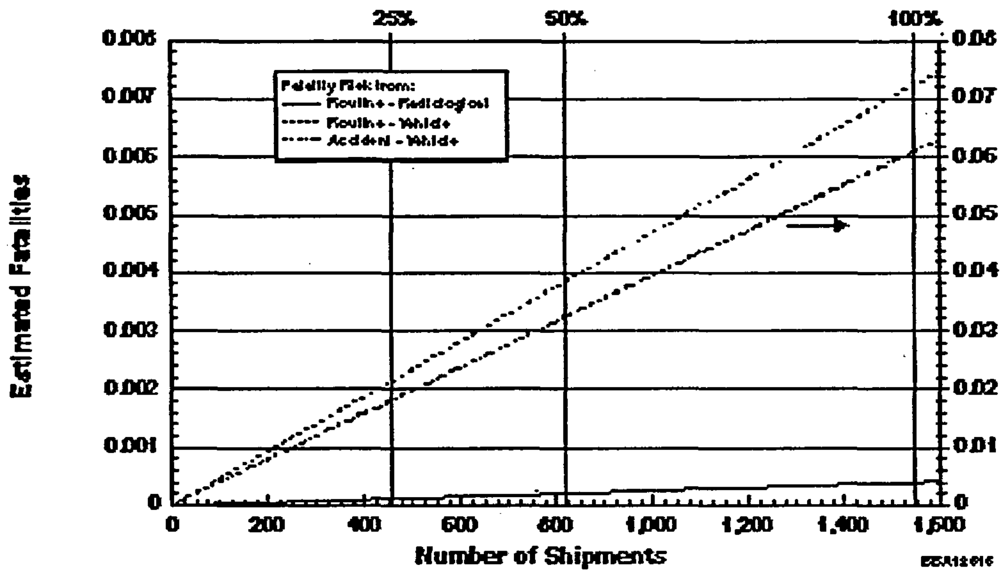

FIGURE K.85 Estimated Truck Transportation Risks for Shipment of LLW from the Metal Cask Manufacturing Facility to a Disposal Site

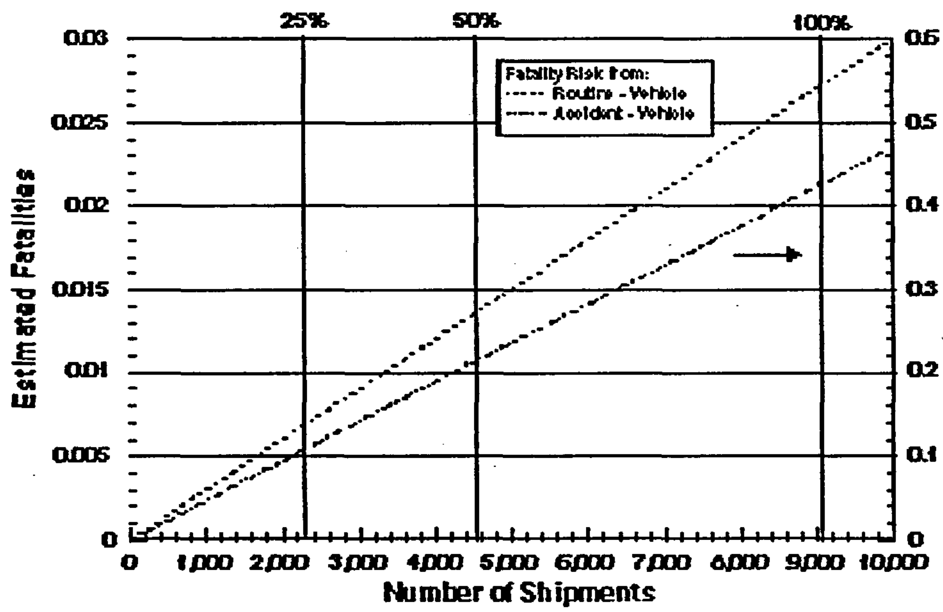

FIGURE K.86 Estimated Rail Transportation Risks for Shipment of Metal Casks from the Cask Manufacturing Facility to an End-User Site

K.6.4 Disposal as Ungrouted U_3O_8

The estimated transportation risks for shipment of all the U_3O_8 from a conversion facility to a disposal site are presented in Appendix J, Section J.3.7. The parametric risks for the oxide shipments are presented in Figures K.87 and K.88 for shipment by truck or rail, respectively.

K.7 IMPACTS OF COMBINATIONS OF ALTERNATIVES

The alternatives evaluated in detail in the PEIS are no action, long-term storage as UF_6, long-term storage as uranium oxide, use as uranium oxide, use as uranium metal, and disposal. DOE's preferred alternative is also considered in the PEIS. This section provides examples of how the impacts of parametric cases for continued storage, cylinder preparation, conversion, long-term storage, manufacture and use, disposal, and transportation activities (as presented in Appendixes D and E and Sections K.2-K.6 of Appendix K) can be added together to assess the impacts of strategies that combine one or more of the alternatives evaluated in the PEIS. Six example combinations of use as oxide, use as metal, and continued storage as UF_6 are evaluated (cases 1 through 6); an additional combination of 50% use as oxide, 50% use as metal (case 7) is also evaluated. Although these combinations were chosen as examples, the methods to calculate potential environmental impacts for them can be used to calculate impacts for other combinations as well (e.g., 50% disposal, 50% long-term storage).

The example combinations assessed (Table K.6) were selected to provide a reasonable range of possible combinations that might occur in the future as uses are identified. A summary of potential environmental consequences associated with these cases is presented in Tables K.9 and K.10 (tables follow Section K.7.2 of this appendix).

K.7.1 Example Calculation of Impacts for a Combination of Alternatives

The results of a sample calculation for Case 1 are presented in Sections K.7.1.1 through K.7.1.11. Under Case 1, 50% of the depleted UF_6 inventory would continue to be stored as UF_6, 25% would be converted and used as uranium oxide, and the remaining 25% would be converted and used as uranium metal. This sample is intended to illustrate how the impacts can be estimated for any combination of alternatives.

The impacts for this sample combination include impacts during continued cylinder storage, preparation of cylinders for shipment, conversion of UF_6 to uranium oxide and metal, treatment of empty cylinders, manufacture of uranium oxide and uranium metal casks, and transportation of cylinders, conversion products (oxide, metal, HF, ammonia, and waste), and casks. The potential impacts of Case 1 were calculated by adding the impacts from each of the individual components, as appropriate. Certain impacts, such as the dose to MEIs, are not additive because the MEI at each

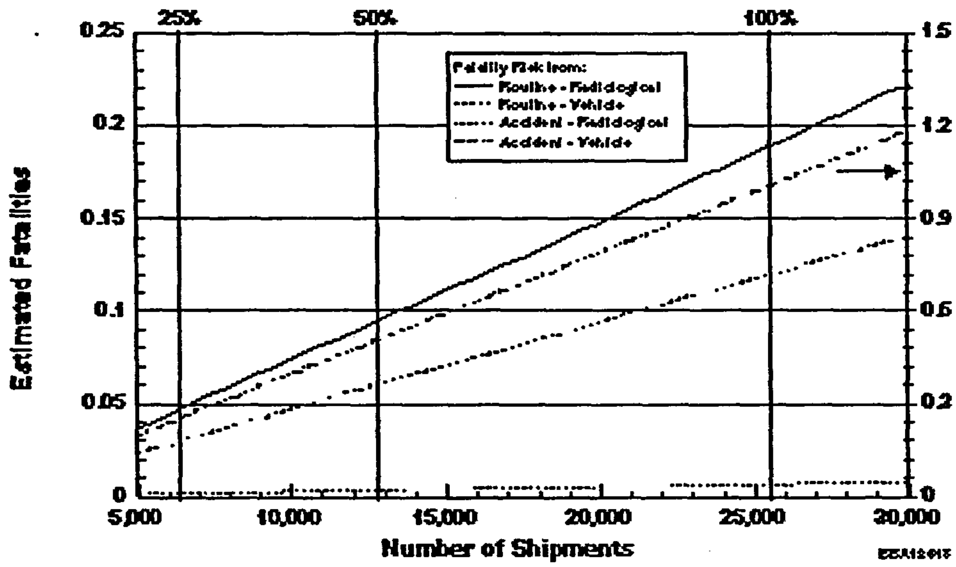

FIGURE K.87 Estimated Truck Transportation Risks for U_3O_8 Shipped from the Conversion Facility to Disposal

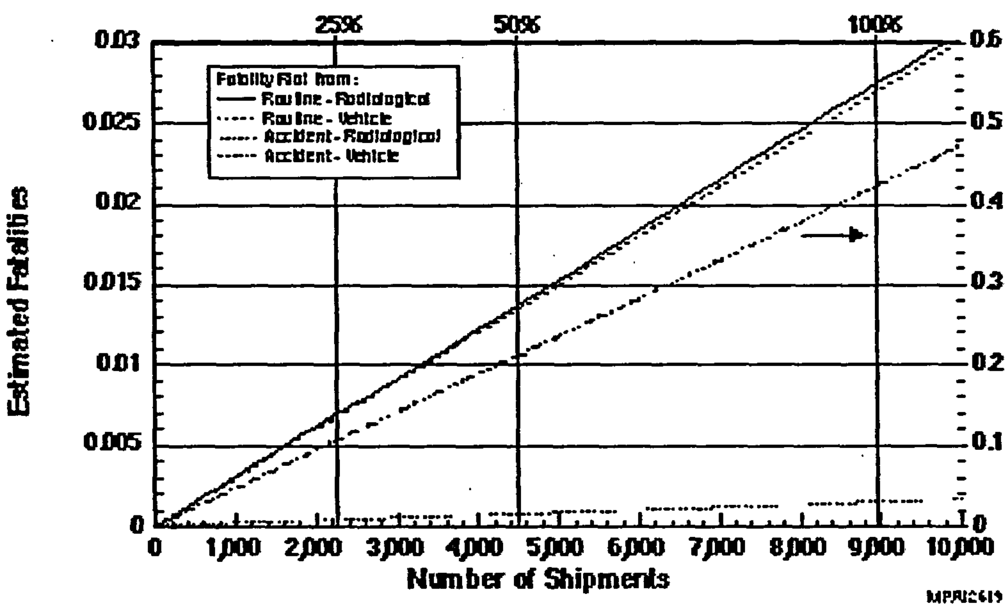

FIGURE K.88 Estimated Rail Transportation Risks for U_3O_8 Shipped from the Conversion Facility to Disposal

TABLE K.6 Example Combinations of Alternatives (Cases) for Which Environmental Impacts Were Evaluated

	Fraction of Inventory		
Case	Use as Uranium Oxide	Use as Uranium Metal	Continued Storage as UF_6 (No Action Alternative)
1	0.25	0.25	0.5
2	0.33	0.33	0.33
3	0.5	0	0.5
4	0	0.5	0.5
5	0.5	0.25	0.25
6	0.25	0.5	0.25
7	0.5	0.5	0

site would be different and the future facilities were assumed to be built at separate sites (except for the continued storage and cylinder preparation activities, which were assumed to occur at the current storage sites; and the conversion and cylinder treatment activities, which would likely occur at the same sites). The potential impacts from continued cylinder storage and cylinder preparation are provided in Appendices D and E, respectively; impacts from the other components are provided in Sections K.1 through K.6.

K.7.1.1 Human Health — Normal Operations

K.7.1.1.1 Radiological Impacts

Involved Workers. The collective radiation dose to involved workers was estimated by summing the radiation dose from each of the components comprising Case 1. The calculation of radiological impacts to involved workers is outlined below. The impacts are first presented for each of the individual components and then summed, as appropriate, to provide an estimate of the total radiological impact.

Continued Cylinder Storage. Potential radiological impacts during continued cylinder storage at the three current storage sites include impacts during storage of 100% of the inventory for a period of 10 years, removal of 50% of the cylinder inventory over a period assumed to be 20 years, and storage of 50% of the inventory for the remaining 10 years considered during the assessment period (1999 through 2039).

The total dose to involved workers was calculated as follows:

Annual dose to involved workers from storage of the entire cylinder inventory (from Table D.2) = 36 person-rem/yr

Average annual dose from storage of 50% of the entire inventory = 0.5 × 36 person-rem/yr = 18 person-rem/yr

Average annual dose during the cylinder removal period for removal of 50% of the inventory = 0.5 × (36 person-rem/yr + 18 person-rem/yr) = 27 person-rem/yr

The total worker dose from continued cylinder storage of 50% of the inventory was then calculated as:

Total worker dose = 10 years × 36 person-rem/yr + 20 years × 27 person-rem/yr + 10 years × 18 person-rem/yr

Total worker dose = 1,080 person-rem

Cylinder Preparation. For purposes of assessing Case 1, it was assumed that the 50% of the cylinder inventory converted for use would be transported to a conversion site from the three current storage sites and that all of the cylinders transported would require preparation by either placement in overcontainers or transfer to new cylinders. Shipment of 50% of the cylinder inventory over a 20-year period corresponds to annual rates of 709 cylinders per year at the Paducah site, 335 cylinders per year at the Portsmouth site, and 117 cylinders per year at the K-25 site.

The annual collective dose to workers for a range of shipment rates at each site are provided in Appendix E, Figure E.3, for the overcontainer option and in Figure E.4 for the transfer facility option. The doses corresponding to the above shipment rates are as follows:

Annual dose to workers using overcontainer option = 14 person-rem/yr (Paducah) + 6 person-rem/yr (Portsmouth) + 2 person-rem/yr (K-25) = 22 person-rem/yr

Total dose over 20 years using overcontainer option = 22 person-rem/yr × 20 years = 440 person-rem

Annual dose to workers using cylinder transfer option = 35 person-rem/yr (Paducah)
+ 25 person-rem/yr (Portsmouth) + 20 person-rem/yr (K-25) = 80 person-rem/yr

Total dose over 20 years using cylinder transfer option = 80 person-rem/yr × 20 years
= 1,600 person-rem

Total range of worker dose from cylinder preparation = 440 to 1,600 person-rem

Conversion. The doses to workers from conversion for various throughput rates are provided in Figure K.11 for conversion to uranium oxide (UO_2) and in Figure K.17 for conversion to uranium metal. From these data, the estimated collective worker doses for conversion of 25% of the inventory to oxide and 25% to uranium metal are as follows:

Annual dose to workers from conversion of 25% of the inventory to oxide
= 22 to 31 person-rem/yr

Total worker dose from conversion to oxide = (22 to 31) person-rem/yr
× 20 years = 440 to 620 person-rem

Annual dose to workers from conversion of 25% of the inventory to metal
= 18 to 50 person-rem/yr

Total worker dose from conversion to metal = (18 to 50) person-rem/yr
× 20 years = 360 to 1,000 person-rem

Cylinder Treatment. The collective dose to workers from the treatment of empty cylinders for a range in the number of cylinders treated is provided in Figure K.23. It was assumed that two treatment facilities would be required, one for each conversion facility. On this basis, the estimated doses to workers are as follows:

Annual dose to workers from treatment of 25% of the cylinder inventory
= 6 person-rem/yr

Total worker dose from cylinder treatment = 2 × 6 person-rem/yr
× 20 years = 240 person-rem

Manufacture and Use. The doses to workers from manufacture and use for various throughput rates are provided in Figure K.41 for manufacture of uranium oxide (UO_2) shielded casks and in Figure K.47 for manufacture of uranium metal shielded casks. From these data, the estimated worker doses for manufacture of 25% of the inventory to oxide shielded casks and 25% to uranium metal shielded casks are as follows:

Annual dose to workers from manufacture of 25% of the inventory to oxide casks
= 10 person-rem/yr

Total worker dose from manufacture of oxide casks
= 10 person-rem/yr × 20 years = 200 person-rem

Annual dose to workers from manufacture of 25% of the inventory to metal casks
= 2 person-rem/yr

Total worker dose from manufacture of metal casks
= 2 person-rem/yr × 20 years = 40 person-rem

Total Radiological Impacts to Workers. The total collective radiation dose to involved workers was calculated by summing the collective doses from the individual components. The individual contributions, as well as the total dose, are summarized in Table K.7. In addition, the number of radiation-induced health effects was estimated by multiplying the collective dose by a health risk conversion factor of 4×10^{-4} LCF/person-rem for involved workers. The total LCFs among workers were estimated to range from 1 to 2 over the duration of the program. The radiological impacts to noninvolved workers would be negligible compared to those for involved workers (based on total doses for individual component activities two or more orders of magnitude lower than those for involved workers).

General Public. The collective radiation dose to members of the general public was calculated in a manner similar to that outlined above for workers. However, because the collective dose to members of the public in the vicinity of all sites was found to be well below levels expected to cause adverse health effects for all individual components, a conservative approach was taken to estimate the total impacts. The total impacts to members of the general public were conservatively estimated by summing the maximum dose estimates (100% cases) for each component, as follows:

Maximum collective dose to public from continued cylinder storage (Table D.1)
= 1.1 person-rem

Maximum collective dose to public from cylinder preparation (Table E.1)
= 0.006 person-rem

TABLE K.7 Range of Radiological Doses and Latent Cancer Fatalities among Involved Workers for Case 1: 50% Continued Storage, 25% Use as Oxide, and 25% Use as Metal

Component	Collective Dose (person-rem)
Continued cylinder storage	1,080
Cylinder preparation	440 – 1,600
Oxide conversion	440 – 620
Metal conversion	360 – 1,000
Cylinder treatment	240
Manufacture of oxide casks	200
Manufacture of metal casks	40
Total dose	2,800 – 4,780
Latent cancer fatalities[a]	1 – 2

[a] The number of latent cancer fatalities was calculated using a health risk conversion factor of 4×10^{-4} LCF/person-rem for workers.

Maximum collective dose to public from conversion to oxide (Table F.2)
= 10 person-rem

Maximum collective dose to public from conversion to metal (Table F.2)
= 8 person-rem

Maximum collective dose to public from cylinder treatment (Table F.2)
= 0.008 person-rem

Maximum collective dose to public from manufacture of oxide casks (Table H.1)
= 0.1 person-rem

Maximum collective dose to public from manufacture of metal casks (Table H.1)
= 0.7 person-rem

The maximum total collective dose to the public is estimated to be approximately 20 person-rem, much less than levels expected to cause adverse health effects.

Because individual activities would occur at separate sites and the results of the parametric analyses indicate that impacts decrease with a decrease in the amount processed, the dose to general public MEIs from Case 1 (as well as any of the other combinations analyzed) would be less than the estimates presented for each of the individual components. Therefore, all doses to individual members of the general public would be well below regulatory limits and well below levels expected to cause adverse health effects.

K.7.1.1.2 Chemical Impacts

Chemical impacts from components comprising Case 1 are generally nonadditive because these impacts were estimated for MEIs at each site and future facilities were assumed to be built at separate sites. The two exceptions are (1) continued storage and cylinder preparation activities, which would take place at the current storage sites; and (2) conversion and cylinder treatment activities, which would likely occur at the same site.

Estimated hazard indices for MEIs for all management options are much less than 1 (a hazard index of greater than 1 indicates the potential for health impacts). To provide a conservative estimate of potential hazards from activities occurring at the same sites, the maximum hazard index for both workers and the general public from continued cylinder storage activities for 1999 through 2039 (0.065; Tables D.5 and D.25) was added to the maximum hazard index from cylinder preparation activities (6.1×10^{-6}; Section E.3.1.2). Similarly, the maximum hazard index from conversion options (1.5×10^{-4}; Table F.6) was added to the maximum hazard index from cylinder treatment (7.1×10^{-8}; Table F.6). The results in both cases are still much lower than 1, so adverse chemical impacts from normal operations would not be associated with Case 1 (or any of the other combinations analyzed).

K.7.1.2 Human Health — Accident Conditions

K.7.1.2.1 Radiological and Chemical Impacts

For any combination involving continued cylinder storage and use as oxide and metal, the bounding impacts from accidents involving radiological or chemical releases would be the largest of the impacts estimated for the no action (continued storage) alternative, the use as oxide alternative, or the use as metal alternative. The consequences of bounding accidents for combination alternatives would be the same as the largest consequences of accidents under these alternatives because only a limited amount of material would be at risk of release under accident conditions, regardless of the facility size or throughput. Although the frequencies of some accidents (for example, cylinder-handling accidents) would decrease somewhat as the facility throughput decreased, the overall frequency category for those accidents would remain the same despite these small changes in frequencies.

K.7.1.2.2 Physical Hazards

Physical hazards to involved and noninvolved workers were estimated by summing the injury and fatality hazards from each of the components comprising the combination, similar to the method described for estimating collective worker radiation dose in Section K.7.1.1.1. For Case 1, the calculations to estimate physical hazards are outlined below.

Continued Cylinder Storage. The numbers of fatalities and injuries during continued cylinder storage at the three current storage sites were estimated by summing the numbers estimated for 10 years of storage of the entire inventory, 20 years for removal of 50% of the cylinder inventory, and 10 additional years for storage of the remaining 50% of the inventory (covering the assessment period 1999 through 2039). The total number of fatalities and injuries to workers was calculated as follows:

Annual fatalities during storage of 100% of the inventory (no action) (from Table D.1)
= 0.11/40 years = 0.0028 fatalities per year

Annual injuries during storage of 100% of the inventory (from Table D.1)
= 143/40 years = 3.6 injuries per year

Annual fatalities during storage of 50% of the inventory
= 0.5 × 0.0028 = 0.0014 fatalities per year

Annual injuries during storage of 50% of the inventory
= 0.5 × 3.6 = 1.8 injuries per year

Average annual fatalities during the removal of 50% of the inventory
= 0.5 × (0.0028 fatalities per year + 0.0014 fatalities per year)
= 0.0021 fatalities per year

Average annual injuries during the removal of 50% of the inventory
= 0.5 × (3.6 injuries per year + 1.8 injuries per year)
= 2.7 injuries per year

The total number of fatalities and injuries from continued storage of 50% of the inventory was calculated as follows:

Total fatalities = 10 years × 0.0028 fatalities per year + 20 years × 0.0021 fatalities per year + 10 years × 0.0014 fatalities per year = 0.08 fatalities

Total injuries = 10 years × 3.6 injuries per year + 20 years × 2.7 injuries per year + 10 years × 1.8 injuries per year = 108 injuries

Cylinder Preparation. For purposes of assessing Case 1, it was assumed that the 50% of the cylinder inventory converted for use would be transported to a conversion site from the three current storage sites and that all of the cylinders transported would require preparation by either placement in overcontainers or transfer to new cylinders. Shipment of 50% of the cylinder inventory over a 20-year period corresponds to annual rates of 709 cylinders per year at the Paducah site, 335 cylinders per year at the Portsmouth site, and 117 cylinders per year at the K-25 site.

The fatalities and injuries for workers conducting overcontainer operations are provided in Appendix E, Figure E.10; the fatalities and injuries for workers conducting transfer operations are provided in Figures E.11 and E.12. These data are estimates of the total fatalities and injuries over the entire 20-year period that cylinder preparation activities were assumed to be ongoing. The estimated number of fatalities and injuries corresponding to shipment of 50% of the inventory at each site are as follows:

Fatalities among workers conducting overcontainer operations = 0.043 (Paducah) + 0.02 (Portsmouth) + 0.007 (K-25) = 0.07 fatalities

Injuries among workers conducting overcontainer operations = 57 (Paducah) + 27 (Portsmouth) + 9 (K-25) = 93 injuries

Fatalities among workers conducting cylinder transfer operations = 0.32 (Paducah) + 0.27 (Portsmouth) + 0.15 (K-25) = 0.74 fatalities

Injuries among workers conducting cylinder transfer operations = 218 (Paducah) + 159 (Portsmouth) + 100 (K-25) = 477 injuries

Total range of fatalities from cylinder preparation option = 0.07 to 0.74 fatalities

Total range of injuries from cylinder preparation option = 93 to 477 injuries

Conversion. The estimated numbers of fatalities and injuries for conversion of various throughput rates are provided in Section K.2.2.3. The estimated numbers of fatalities and injuries from conversion for Case 1 are as follows:

Fatalities among workers from conversion of 25% of the inventory to oxide
= 0.35 to 0.49 fatalities

Injuries among workers from conversion of 25% of the inventory to oxide
= 290 to 430 injuries

Fatalities among workers from conversion of 25% of the inventory to metal
= 0.33 to 0.49 fatalities

Injuries among workers from conversion of 25% of the inventory to metal
= 270 to 450 injuries

Cylinder Treatment. The estimated numbers of fatalities and injuries from the treatment of empty cylinders for a range in the number of cylinders treated is provided in Section K.2.2.3. In the case of conversion to both metal and oxide, two separate conversion facilities with separate cylinder treatment facilities would likely be constructed, so the impacts would be two times the 25% impacts, rather than the impacts for a single 50% capacity treatment facility. The estimated numbers of fatalities and injuries from cylinder treatment for Case 1 are as follows:

Fatalities among workers from treatment of 25% of the cylinder inventory = 0.13 fatalities

Injuries among workers from treatment of 25% of the cylinder inventory = 121 injuries

Total fatalities = 2 × 0.13 = 0.26 fatalities

Total injuries = 2 × 121 = 242 injuries

Manufacture and Use. Fatalities and injuries for manufacture of uranium oxide (UO_2) shielded casks are presented in Figure K.49; values for manufacture of uranium metal shielded casks are presented in Figure K.50. The estimated numbers of fatalities and injuries for Case 1 are as follows:

Fatalities among workers from manufacture of 25% of the inventory to oxide casks
= 0.61 fatalities

Injuries among workers from manufacture of 25% of the inventory to oxide casks
= 490 injuries

Fatalities among workers from manufacture of 25% of the inventory to metal casks
= 0.68 fatalities

Injuries among workers from manufacture of 25% of the inventory to metal casks
= 520 injuries

Total Physical Hazards. The total fatalities and injuries were calculated by summing the values for the individual components and then rounding to the nearest whole number. The individual contributions and total fatalities and injuries are summarized in Table K.8.

K.7.1.3 Transportation

The transportation impacts for normal operations and traffic accident fatalities were determined by the number of shipments required for each combination alternative, assuming a travel distance of 620 miles (1,000 km) per shipment. For Case 1, these impacts would be the sum of the number of shipments if 25% of the inventory was converted for use as oxide and 25% of the inventory was converted for use as metal (no off-site transportation of cylinders would be required

TABLE K.8 Range of On-the-Job Fatalities and Injuries among All Workers for Case 1: 50% Continued Storage, 25% Use as Oxide, and 25% Use as Metal[a]

Component	Fatalities	Injuries
Continued cylinder storage	0.08	110
Cylinder preparation	0.07 – 0.74	93 – 480
Oxide conversion	0.35 – 0.49	290 – 430
Metal conversion	0.33 – 0.49	270 – 450
Cylinder treatment	0.26	240
Manufacture of oxide casks	0.61	490
Manufacture of metal casks	0.68	520
Total	2 – 3	2,000 – 2,700

[a] Represents impacts to involved and noninvolved workers from construction and operation of facilities. Values rounded to two significant figures.

for continued cylinder storage). The impacts of the various combinations examined would be essentially the same for exposures from normal operations because these exposures would generally be expected to result in 1 or fewer adverse health effects among workers and members of the general public combined. As would be expected, traffic accident fatalities for Case 1, which would involve transportation of 50% of the cylinder inventory and the resulting conversion products, are estimated to be about half of those expected under the use as oxide and use as metal alternatives (Table K.9, which follows Section K.7.2 of this appendix).

For any combination involving continued cylinder storage and use as oxide and metal, the bounding impacts for accidents involving releases from cylinders or releases of other materials would be the larger of the impacts estimated for either the use as oxide alternative or the use as metal alternative. The consequences of bounding accidents for combination alternatives would be the same as the largest consequences of these alternatives because the same amount of material would be at risk under accident conditions, regardless of the number of shipments. The overall probability of accidents occurring would decrease in direct proportion to the number of shipments and the distance per shipment; in Case 1, the overall probability would be about half that estimated for the use as oxide alternative.

K.7.1.4 Air Quality

Air quality impacts from construction at the current storage sites would be the same as those predicted for the no action alternative because all construction activities are planned to take place prior to about 2003, during which time all cylinders would remain at the current storage locations under all alternatives and combination alternatives examined.

Air quality impacts from operations at the current storage sites for combination alternatives involving varying percentages of continued storage would depend on whether a certain percentage of cylinders was removed from each site or whether cylinders were preferentially removed from one or two of the sites. For 100% continued storage (no action alternative), a potential impact that could occur if cylinder maintenance and painting activities do not reduce cylinder corrosion rates would be exceedance of the HF standard at the K-25 site in about the year 2020 (see Appendix D, Section D.3, for further discussion).

In examining the potential air quality impacts of combination alternatives, the case where cylinders at the Paducah and Portsmouth sites would be preferentially removed for use was assumed as the bounding case, leaving all cylinders in place at the K-25 site. (The number of cylinders stored at the K-25 site constitutes only about 10% of the entire inventory, so that the combination alternatives that consider from 25 to 75% use of the inventory could all have the entire K-25 inventory remaining in place). Therefore, the bounding air quality impacts from operations at the current storage sites for combination alternatives (including Case 1) would be the same as the impacts from the no action alternative. If the cylinders at K-25 were preferentially removed or part of the inventory was removed, then air quality impacts at the K-25 site would decrease accordingly. Also, if continued maintenance and painting are effective in controlling cylinder corrosion, as expected, concentrations of HF would be kept within regulatory standards at all sites under all combination alternatives.

Pollutant emissions during construction and operation of conversion and manufacturing facilities designed to process the entire inventory would remain within standards. Emissions under the combination alternatives also would remain within standards because emissions were estimated to be within applicable standards for full-scale (100%) facilities and emissions would be somewhat reduced for facilities with lower throughput rates because different sites were assumed for new facilities.

K.7.1.5 Water and Soil

As discussed for air quality impacts, impacts to groundwater at the current storage sites for combination alternatives involving varying percentages of continued storage would depend on whether a certain percentage of cylinders was removed from each site or whether cylinders were preferentially removed from one or two of the sites. For the no action alternative, a potential impact that could occur if cylinder maintenance and painting activities do not reduce cylinder corrosion rates would be that the groundwater uranium concentration at all three sites could exceed 20 µg/L in about the year 2100 or later (see Appendix D, Section D.3, for further discussion). For combination alternatives, the case where cylinders at the Paducah and Portsmouth sites would be preferentially removed for use was assumed as the bounding case, leaving all cylinders in place at the K-25 site. Therefore, the bounding groundwater quality impacts at the current storage sites for combination alternatives could include exceedance of the 20 µg/L guideline level at one or more of the current storage sites at some time after the year 2100. However, if cylinder maintenance and painting are effective in controlling cylinder corrosion, as expected, groundwater uranium concentrations would remain below 20 µg/L at all sites.

Potential surface water, groundwater and soil quality impacts at conversion and manufacturing facilities could be kept within applicable standards or guidelines by following good engineering practices.

K.7.1.6 Socioeconomics

Socioeconomic impacts for each component of the combination alternatives are summarized in Tables K.9 and K.10 (which follow Section K.7.2). Methods of estimating these impacts are discussed in Sections K.7.1.6.1 and K.7.1.6.2.

K.7.1.6.1 Continued Cylinder Storage

Socioeconomic impacts from construction activities at the current storage sites would be the same as those predicted for the no action alternative because all construction activities are planned to take place prior to about 2003, during which time all cylinders would remain at the current storage locations under all alternatives and combination alternatives examined.

The socioeconomic analysis evaluated direct income and jobs for the first year of operations. These values may be interpreted as annual averages over the operational periods because annual operations would generally be uniform. Continued storage impacts for combination alternatives need to be normalized to a standard number of years because continued storage would be ongoing for about 40 years (1999 through 2039), whereas use options were assumed to be ongoing for only 20 years (2009 through 2028). For continued storage operations, the totals for direct jobs and direct income were calculated as follows:

Direct jobs during storage (no action), three-site total (from Table D.18)
= 110 jobs per year

Direct income during storage, three-site total (from Table D.18)
= $5.1 million per year

Direct jobs during cylinder removal (action alternatives), three-site total (from Table D.30)
= 120 jobs per year

Direct income during cylinder removal, three-site total (from Table D.30)
= $6 million per year

Average jobs during the removal of 50% of the inventory = 0.5 × (110 jobs per year
+ 120 jobs per year) = 115 jobs per year

Average income during the removal of 50% of the inventory = 0.5 × ($5.1 million/yr
+ $6 million per year) = $5.55 million per year

The total jobs and income from continued storage of 50% of the inventory was calculated as follows:

Total jobs = 10 years × 110 jobs per year + 20 years × 115 jobs per year
+ 10 years × 55 jobs per year = 3,950 job-years

Total income = 10 years × $5.1 million per year + 20 years × $5.55 million per year
+ 10 years × $2.55 million per year) = $187.5 million

To facilitate comparison with the no action alternative, the total jobs and income were distributed over 40 years, resulting in a value of 99 jobs per year and $4.7 million income per year over 40 years (see Table K.9). To compare with use alternatives, the values should be converted to total jobs, assuming 40 years for no action and combination alternatives involving continued storage, and assuming 20 years for alternatives involving use only.

K.7.1.6.2 Cylinder Preparation, Conversion, and Manufacturing

Parametric socioeconomic impacts for the cylinder preparation, conversion, and manufacturing options were assessed qualitatively (see Sections E.3.5, K.2.5, and K.4.5), based on preliminary cost data for the 100% cases (LLNL 1996) and socioeconomic data for parametric cases provided in the cost analysis report (LLNL 1997b). The estimated direct jobs and direct employment values for combination alternatives calculated using the above-described data are presented in Tables K.9 and K.10.

K.7.1.7 Ecology

The principal differences in ecological impacts between the combination alternatives would be associated with habitat loss. Potential habitat loss at the current storage sites is the sum of habitat loss that would occur under the no action alternative (7 acres [2.8 ha]), which would be applicable for all alternatives because construction would occur prior to 2003) and loss that would occur from cylinder preparation activities. If overcontainers were used, no additional habitat loss would occur. Transfer facilities would range in areal site requirements from about 12 acres (4.9 ha) for a facility to process the inventory at the K-25 site (10% of the entire inventory), to 14 acres (5.7 ha) for a facility to process the inventory at the Portsmouth site (30% of the entire inventory), to 21 acres (8.5 ha) for a facility to process the inventory at the Paducah site (60% of the entire inventory) (see Section E.3.6). For alternatives involving 100% use, the maximum habitat loss at any site would be 28 acres (21 + 7) (11 ha). To estimate habitat loss for alternatives involving 50 to 75% use, it was assumed that all cylinders would be taken from a single facility until the entire inventory at a single site was used. Therefore, maximum habitat loss at any site for a 50% use facility would be estimated at 21 acres (8.5 ha) (Paducah site value) + 7 acres (2.8 ha), or 28 acres (11 ha). Similarly, maximum habitat loss at any site for alternatives involving 75% use would also be 28 acres (11 ha).

Potential habitat loss for conversion facilities was calculated on the basis of data provided in Sections K.2.9.2, K.2.9.3, and K.2.9.4. The habitat losses corresponding to 25%, 50% and 100% capacity uranium oxide (UO_2) conversion facilities would be 16, 19, and 24 acres (6.5, 7.7, and 9.7 ha), respectively. Similarly, the habitat losses corresponding to 25%, 50% and 100% capacity metal conversion facilities would be 17, 21, and 26 acres (6.9, 8.5, and 10.5 ha), respectively. Finally, for 25%, 50%, and 100% cylinder treatment facilities, the habitat losses would be 7, 8, and 9 acres

(2.8, 3.2, and 3.6 ha), respectively. Although these parametric values were calculated for specific conversion options (e.g., conversion to UO_2 by the dry process, with anhydrous HF production), the amount of land required for the other conversion technologies would be roughly similar. For combination options involving both oxide and metal conversion, two cylinder treatment facilities would be required, one for each conversion facility. The habitat loss for conversion for Case 1 (25% use as oxide, 25% use as metal) was calculated as follows:

Habitat loss for conversion to oxide = 16 acres (6.5 ha)

Habitat loss for conversion to metal = 17 acres (6.9 ha)

Habitat loss for a treatment facility = 7 acres (2.8 ha)

Habitat loss for each conversion facility = 23 to 24 acres (9.3 to 9.7 ha) (total of 47 acres)

Potential habitat loss for manufacturing facilities was calculated on the basis of data given in Section K.4.9. For an oxide cask manufacturing facility, the land areas corresponding to 25%, 50%, and 100% capacity would be 79, 84, and 90 acres (32, 34, and 36 ha), respectively; the land areas for 25%, 50% and 100% capacity at a metal cask manufacturing facility are assumed to be the same. For Case 1, two 25% capacity manufacturing facilities would be required, so the total land area would be about 79 acres (32 ha) at either manufacturing facility (total of 158 acres).

K.7.1.8 Waste Management

For waste management at the current storage sites, impacts for all combination alternatives would be similar to those estimated for the no action alternative. Although waste generation amounts would vary somewhat on the basis of the numbers of cylinders being stored and maintained, overall impacts to nationwide waste generation would be negligible. Waste generation impacts associated with waste management capabilities at the Portsmouth and K-25 sites would be negligible. Due to large amounts of cylinder painting assumed at the Paducah site in the earlier years of continued storage, impacts to LLMW management at the Paducah site would be moderate for all combination alternatives.

The use as oxide and use as metal alternatives have potential moderate impacts to nationwide LLW generation on the basis of a possible requirement to dispose of CaF_2 and/or MgF_2 as LLW, if the CaF_2 or MgF_2 were considered DOE waste. If such disposal were required, these alternatives could generate a volume of LLW equal to about 10% of the projected DOE complexwide disposal volume. Moderate impacts to nationwide waste management are defined as additional volumes in excess of 10% of the DOE complexwide disposal volume; negligible to low impacts generate less than 10%. Assuming a linear decrease in potential LLW production, combination alternatives involving 50% or more conversion to oxide or metal could have low to moderate impacts on nationwide LLW waste management.

K.7.1.9 Resource Requirements

Under the combination alternatives, adverse effects on local, regional, or national availability of materials would not be expected.

K.7.1.10 Land Use

Land use corresponds to habitat loss. See Section K.7.1.7 for an explanation of the values calculated for the combination alternatives.

K.7.1.11 Other Areas of Impact

Impacts to cultural resources at the current storage sites would depend on the selected locations for construction activities but are considered unlikely. Cultural resource activities at other facilities would depend on the locations and will be examined in detail at the next stage of the program when facilities are actually sited. Adverse environmental justice impacts for activities occurring under the example combination alternatives are not expected. The occurrence of severe transportation accidents involving a release is unlikely, and accidents occur at random locations along transportation corridors; therefore, significant and disproportionate high and adverse impacts to minority or low-income populations are unlikely.

K.7.2 Summary of Impacts for Example Combination Alternatives

The method used to estimate the impacts for combination alternatives described in Section K.7.1 was used to evaluate the impacts for the example cases listed in Table K.6. The results for the first six cases analyzed are presented in detail in Table K.9. The results for an additional 50% use as oxide, 50% use as metal combination strategy are presented in Table K.10. In general, the impacts for these combination alternatives tend to be very similar to the impacts estimated for the primary alternatives evaluated in the PEIS (as summarized in Chapter 2, Table 2.2).

TABLE K.9 Summary Comparison of Environmental Consequences of Example Combinations of Use as Oxide, Use as Metal, and Continued Storage as UF_6 Alternatives

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
Human Health and Safety — Normal Facility Operations [a]						
Radiation Exposure						
Involved workers						
Annual dose to individual workers	Monitored to be maintained within maximum regulatory limit of 5 rem/yr or lower	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total health effects among involved workers (1999-2039)	1 to 2 additional LCFs	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Noninvolved workers						
Annual dose to noninvolved worker MEI (all facilities)	Well within public health standards (i.e., less than maximum dose limit of 100 mrem/yr)	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total health effects among noninvolved workers (1999-2039)	0 additional LCFs from routine site emissions	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
General public						
Annual dose to general public MEI (all facilities)	Well within public health standards (i.e., less than maximum dose limit of 100 mrem/yr)	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total health effects among members of the public (1999-2039)	0 additional LCFs from routine site emissions	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Chemical Exposure of Concern (Concern = hazard index > 1)						
Noninvolved worker MEI [b]	No (Hazard Index <1)	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
General public MEI	No (Hazard Index <1)	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Human Health and Safety — Facility Accidents[a]			
Physical Hazards from Construction and Operations (involved and noninvolved workers)						
On-the-job fatalities and injuries (1999-2039)	2-3 fatalities; 2,000-2,700 injuries	2-3 fatalities; 2,100-2,800 injuries	1-2 fatalities; 1,200-1,700 injuries	1-2 fatalities; 1,200-1,800 injuries	3-4 fatalities; 2,200-2,900 injuries	3-4 fatalities; 2,100-2,900 injuries
Accidents Involving Releases of Chemicals or Radiation: Cylinder Accidents at Current Storage Sites						
Likely Cylinder Accidents[c]						
Accident[d]	Corroded cylinder spill, dry conditions	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Release	Uranium, HF	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Estimated frequency	~ 1 in 10 years	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident probability (1999-2039)	3-4 potential accidents	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Consequences (per accident)						
Chemical exposure – public	No adverse effects	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Chemical exposure – noninvolved workers[e]						
Adverse effects	70	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Irreversible adverse effects	3	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Radiation exposure – public						
Dose to MEI	3 mrem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Risk of LCF	1 in 1 million	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total dose to population	0.4 person-rem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total LCFs	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Radiation exposure – noninvolved workers[e]						
Dose to MEI	77 mrem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Risk of LCF	3 in 100,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total dose to workers	2.2 person-rem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total LCFs	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident risk (consequence times probability)						
General public	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Workers	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
Human Health and Safety — Facility Accidents[a] (Cont.)						
Accidents Involving Releases of Chemicals or Radiation: Cylinder Accidents at Current Storage Sites (Cont.)						
Low Frequency-High Consequence Cylinder Accidents[f]						
Accidents[d]	Vehicle-induced fire, 3 full cylinders (high for adverse effects); corroded cylinder spill, wet conditions (high for irreversible adverse effects)	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Release	Uranium, HF	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Estimated frequency	~ 1 in 100,000 years	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident probability (1999-2039)	~ 1 chance in 2,500	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Consequences (per accident)						
Chemical exposure – public						
Adverse effects	1,900	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Irreversible adverse effects	1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Chemical exposure – noninvolved workers[e]						
Adverse effects	1,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Irreversible adverse effects	300	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	3	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Radiation exposure – public						
Dose to MEI	15 mrem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Risk of LCF	7 in 1 million	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total dose to population	1 person-rem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total LCFs	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Radiation exposure – noninvolved workers[e]						
Dose to MEI	20 mrem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Risk of LCF	8 in 1 million	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total dose to workers	16 person-rem	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Total LCFs	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident risk (consequence times probability)						
General public	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Noninvolved workers	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
Human Health and Safety — Facility Accidents[a] (Cont.)						
Accidents Involving Releases of Chemicals or Radiation: Low Frequency-High Consequence Accidents at All Facilities[f]						
Chemical accident[d]	HF or NH_3 tank rupture	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Release	HF, NH_3	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident location	Conversion site	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Estimated frequency	< 1 in 1 million years	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident probability (1999-2039)	1 chance in 50,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Consequences (per accident)						
Chemical exposure – public						
Adverse effects	41,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Irreversible adverse effects	1,700	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	30	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Chemical exposure – noninvolved workers[e]						
Adverse effects	1,100	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Irreversible adverse effects	440	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	4	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident risk (consequence times probability)						
General public	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Noninvolved workers[e]	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Radiological accident[d]	Earthquake damage to storage building at conversion site	Same as Case 1	Same as Case 1	Vehicle-induced fire, 3 full cylinders	Same as Case 1	Same as Case 1
Release	Uranium (UO_2)	Same as Case 1	Same as Case 1	Uranium	Same as Case 1	Same as Case 1
Accident location	Conversion site	Same as Case 1	Same as Case 1	Conversion site	Same as Case 1	Same as Case 1
Estimated frequency	1 in 100,000 years	Same as Case 1	Same as Case 1	1 in 100,000 years	Same as Case 1	Same as Case 1
Accident probability (1999-2039)	1 chance in 5,000	Same as Case 1	Same as Case 1	1 chance in 5,000 (over 20 years)	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
Human Health and Safety — Facility Accidents[a] (Cont.)						
Accidents Involving Releases of Chemicals or Radiation: Low Frequency-High Consequence Accidents at All Facilities[f] (Cont.)						
Consequences (per accident)						
Radiation exposure – public						
Dose to MEI	68 mrem	Same as Case 1	Same as Case 1	15 mrem	Same as Case 1	Same as Case 1
Risk of LCF	3 in 100,000	Same as Case 1	Same as Case 1	7 in 1 million	Same as Case 1	Same as Case 1
Total dose to population	5.1 person-rem	Same as Case 1	Same as Case 1	56 person-rem	Same as Case 1	Same as Case 1
Total LCFs	0	Same as Case 1	Same as Case 1	0	Same as Case 1	Same as Case 1
Radiation exposure – noninvolved workers[e]						
Dose to MEI	2,300 mrem	Same as Case 1	Same as Case 1	20 mrem	Same as Case 1	Same as Case 1
Risk of LCF	9 in 10,000	Same as Case 1	Same as Case 1	8 in 1 million	Same as Case 1	Same as Case 1
Total dose to workers	210 person-rem	Same as Case 1	Same as Case 1	8 person-rem	Same as Case 1	Same as Case 1
Total LCFs	0	Same as Case 1	Same as Case 1	0	Same as Case 1	Same as Case 1
Accident risk (consequence times probability)						
General public	0 LCFs	Same as Case 1	Same as Case 1	0 LCFs	Same as Case 1	Same as Case 1
Noninvolved workers[e]	0 LCFs	Same as Case 1	Same as Case 1	0 LCFs	Same as Case 1	Same as Case 1
Human Health and Safety — Transportation[a]						
Major Materials Assumed to Be Transported between Sites	UF_6 cylinders Uranium oxide Uranium metal HF (if produced) CaF_2 (if produced) NH_3 MgF_2 LLW/LLMW Casks	UF_6 cylinders Uranium oxide Uranium metal HF (if produced) CaF_2 (if produced) NH_3 MgF_2 LLW/LLMW Casks	UF_6 cylinders Uranium oxide HF (if produced) CaF_2 (if produced) NH_3 LLW/LLMW Casks	UF_6 cylinders Uranium metal HF (if produced) CaF_2 (if produced) NH_3 MgF_2 LLW/LLMW Casks	UF_6 cylinders Uranium oxide Uranium metal HF (if produced) CaF_2 (if produced) NH_3 MgF_2 LLW/LLMW Casks	UF_6 cylinders Uranium oxide Uranium metal HF (if produced) CaF_2 (if produced) NH_3 MgF_2 LLW/LLMW Casks

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Human Health and Safety — Transportation[a] (Cont.)			
Normal Operations						
Fatalities from exposure to vehicle exhaust and external radiation	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1	0 to 1
Maximum radiation exposure to a person along a route (MEI)	Less than 0.1 mrem	Less than 0.1 mrem	Less than 0.1 mrem	Less than 0.1 mrem	Less than 0.1 mrem	Less than 0.1 mrem
Traffic Accident Fatalities (1999-2039) (physical hazards, unrelated to cargo)						
Maximum use of trucks	2 fatalities	3 fatalities	2 fatalities	2 fatalities	3 fatalities	3 fatalities
Maximum use of rail	1 fatality	1 fatality	1 fatality	1 fatality	1 fatality	1 fatality
Traffic Accidents Involving Releases of Radiation or Chemicals						
Low Frequency-High Consequence Cylinder Accidents						
Accident	Urban rail accident involving 4 cylinders	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Release	Uranium, HF	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident probability (1999-2039)	1 chance in 10,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Consequences (per accident)						
Chemical exposure – All workers and members of general public						
Irreversible adverse effects	4	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Radiation exposure – All workers and members of general public						
Total LCFs	60	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident risk (consequence times probability) – Workers and general public	0 fatalities	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
	Human Health and Safety — Transportation[a] (Cont.)					
Traffic Accidents Involving Releases of Radiation or Chemicals (Cont.)						
Low Frequency-High Consequence Accidents with All Other Materials						
Accident	Urban rail accident involving anhydrous HF	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Release	Anhydrous HF	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident probability (1999-2039)	1 chance in 30,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Consequences (per accident)						
Chemical exposure – All workers and members of general public						
Irreversible adverse effects	30,000	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	300	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Accident risk (consequence times probability)						
Irreversible adverse effects	1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Fatalities	0	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Air Quality			
Current Storage Sites						
Pollutant emissions during construction	Maximum 24-hour PM_{10} concentration up to 95% of standard; other criteria pollutants well within standards	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Pollutant emissions during operations	Maximum 24-hour HF concentration up to 23% of standard at K-25; HF concentrations well within standards at other sites; criteria pollutants well within standards at all sites	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other Facilities[g]						
Pollutant emissions during construction and operations	Maximum 24-hour PM_{10} concentration up to 90% of standard; other pollutant emissions well within standards (all less than 30% of standards)	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Water and Soil[h]			
Current Storage Sites						
Surface water, groundwater, and soil quality	Uranium concentrations would remain within guideline levels	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other parameters[i]	No change	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other Facilities[g]						
Surface water, groundwater, and soil quality	Site-dependent; contaminant concentrations could be kept within guideline levels	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other parameters[i]	Site-dependent; none to moderate impacts	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Excavation of Soil for Long-Term Storage or Disposal	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
			Socioeconomics[j]			
Current Storage Sites						
Continued storage	**Jobs:** 30 peak year, construction; 99 per year over 40 years, operations	**Jobs:** 30 peak year, construction; 94 per year over 40 years, operations	**Jobs:** 30 peak year, construction; 99 per year over 40 years, operations	**Jobs:** 30 peak year, construction; 99 per year over 40 years, operations	**Jobs:** 30 peak year, construction; 93 per year over 40 years, operations	**Jobs:** 30 peak year, construction; 93 per year over 40 years, operations
	Income: \$1.4 million peak year, construction; \$4.7 million per year over 40 years, operations	**Income:** \$1.4 million peak year, construction; \$4.5 million per year over 40 years, operations	**Income:** \$1.4 million peak year, construction; \$4.7 million per year over 40 years, operations	**Income:** \$1.4 million peak year, construction; \$4.7 million per year over 40 years, operations	**Income:** \$1.4 million peak year, construction; \$4.5 million per year over 40 years, operations	**Income:** \$1.4 million peak year, construction; \$4.5 million per year over 40 years, operations

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Socioeconomics[j] (Cont.)			
Current Storage Sites (Cont.)						
Cylinder preparation	**Jobs:** 0-290 peak year, preoperations; 150-250 per year over 20 years operations	**Jobs:** 0-380 peak year, preoperations; 200-320 per year over 20 years, operations	**Jobs:** 0-290 peak year, preoperations; 150-250 per year over 20 years, operations	**Jobs:** 0-290 peak year, preoperations; 150-250 per year over 20 years, operations	**Jobs:** 0-440 peak year, preoperations; 230-370 per year over 20 years, operations	**Jobs:** 0-440 peak year, preoperations; 230-370 per year over 20 years, operations
	Income: $0-13 million peak year, preoperations; $10-13 million per year over 20 years, operations	**Income:** $0-17 million peak year, preoperations; $13-17 million per year over 20 years, operations	**Income:** $0-13 million peak year, preoperations; $10-13 million per year over 20 years, operations	**Income:** $0-13 million peak year, preoperations; $10-13 million per year over 20 years, operations	**Income:** $0-20 million peak year, preoperations; $14-19 million per year over 20 years, operations	**Income:** $0-20 million peak year, preoperations; $14-19 million per year over 20 years, operations
Other Facilities[g]						
Conversion	**Jobs:** 620-960 peak year, construction; 490-720 per year over 20 years, operations	**Jobs:** 670-1,030 peak year, construction; 500-750 per year over 20 years, operations	**Jobs:** 290-630 peak year, construction; 250-380 per year over 20 years, operations	**Jobs:** 420-470 peak year, construction; 270-400 per year over 20 years, operations	**Jobs:** 660-1,000 peak year, construction; 480-710 per year over 20 years, operations	**Jobs:** 670-1,010 peak year, construction; 540-800 per year over 20 years, operations
	Income: $25-41 million peak year, construction; $29-41 million per year over 20 years, operations	**Income:** $27-44 million peak year, construction; $30-42 million per year over 20 years, operations	**Income:** $14-28 million peak year, construction; $15-22 million per year over 20 years, operations	**Income:** $15-18 million peak year, construction; $16-22 million per year over 20 years, operations	**Income:** $27-45 million peak year, construction; $29-40 million per year over 20 years, operations	**Income:** $26-43 million peak year, construction; $31-44 million per year over 20 years, operations

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Socioeconomics[j] (Cont.)			
Other Facilities[g] (Cont.)						
Long-term storage	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Manufacturing	**Jobs:** 270 peak year, construction; 430 per year over 20 years, operations	**Jobs:** 280 peak year, construction; 490 per year over 20 years, operations	**Jobs:** 130 peak year, construction; 260 per year over 20 years, operations	**Jobs:** 160 peak year, construction; 290 per year over 20 years, operations	**Jobs:** 280 peak year, construction; 480 per year over 20 years, operations	**Jobs:** 290 peak year, construction, 480 per year over 20 years, operations
	Income: $13 million peak year, construction; $30 million per year over 20 years, operations	**Income:** $13 million peak year, construction; $34 million per year over 20 years, operations	**Income:** $5.8 million peak year, construction; $18 million per year over 20 years, operations	**Income:** $7.7 million peak year, construction; $20 million per year over 20 years, operations	**Income:** $13 million peak year, construction; $33 million per year over 20 years, operations	**Income:** $13 million peak year, construction; $33 million per year over 20 years, operations
Disposal	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Ecology			
Current Storage Sites						
Habitat loss	Up to 28 acres; negligible to potential moderate impacts	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Concentrations of chemical or radioactive materials	Below harmful levels; potential site-specific effects from facility or transportation accidents	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Wetlands and threatened or endangered species	None to negligible impacts	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other Facilities[g]						
Habitat loss[k]	**Conversion:** Up to 24 acres at a single facility, total of 47 acres; potential moderate impacts to vegetation and wildlife	**Conversion:** Up to 30 acres at a single facility, total of 52 acres; potential moderate impacts to vegetation and wildlife	**Conversion:** Up to 27 acres total; potential moderate impacts to vegetation and wildlife	**Conversion:** Up to 29 acres total; potential moderate impacts to vegetation and wildlife	**Conversion:** Up to 27 acres at a single facility, 51 acres total; potential moderate impacts to vegetation and wildlife	**Conversion:** Up to 29 acres at a single facility, 52 acres total; potential moderate impacts to vegetation and wildlife
	Manufacturing: Up to 79 acres at a single facility, total of 158 acres; potential moderate to large impacts to vegetation and wildlife	**Manufacturing:** Up to 81 acres at a single facility, total of 162 acres; potential moderate to large impacts to vegetation and wildlife	**Manufacturing:** Up to 84 acres total; potential moderate impacts to vegetation and wildlife	**Manufacturing:** Up to 84 acres total; potential moderate impacts to vegetation and wildlife	**Manufacturing:** Up to 84 acres at a single facility, 163 acres total; potential moderate to large impacts to vegetation and wildlife	**Manufacturing:** Up to 84 acres at a single facility, 163 acres total; potential moderate to large impacts to vegetation and wildlife
Concentrations of chemical or radioactive materials	Below harmful levels; potential site-specific effects from facility or transportation accidents	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Wetlands and threatened or endangered species	Site-dependent; avoid or mitigate	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Waste Management			
Current Storage Sites	**LLW:** no impacts **LLMW:** potential moderate impacts with respect to current waste generation at Paducah (> 20%); negligible impacts with respect to Portsmouth, K-25, or nationwide waste generation	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other Facilities[g]						
Conversion	Potential moderate impacts to current nationwide LLW generation for CaF_2 (if produced and not used) and MgF_2 as LLW (if required); potential moderate impact to site waste generation for CaF_2 and MgF_2 as nonhazardous solid waste	Same as Case 1	Potential moderate impacts to current nationwide LLW generation for CaF_2 (if produced and not used) as LLW (if required); potential moderate impact to site waste generation for CaF_2 as nonhazardous solid waste	Potential moderate impacts to current nationwide LLW generation for MgF_2 as LLW (if required), potential moderate impact to site waste generation for MgF_2 as nonhazardous solid waste	Same as Case 1	Same as Case 1
Manufacturing	Negligible impacts with respect to current regional or nationwide waste generation	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
			Resource Requirements [l]			
All Sites	No effects on local, regional, or national availability of materials are expected	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
			Land Use [k]			
Current Storage Sites	Up to 28 acres; less than 1% of available land; negligible impacts	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other Facilities[g]						
Conversion	Up to 24 acres at a single facility, total of 47 acres; negligible impacts	Up to 30 acres at a single facility, total of 52 acres; negligible impacts	Up to 27 acres total; negligible impacts	Up to 29 acres total; negligible impacts	Up to 27 acres at a single facility, 51 acres total; negligible impacts	Up to 29 acres at a single facility, 52 acres total; negligible to potential moderate impacts
Manufacturing	Up to 79 acres at a single facility, total of 158 acres; potential moderate impacts	Up to 81 acres at a single facility, total of 162 acres; potential moderate impacts	Up to 84 acres total; potential moderate impacts	Up to 84 acres total; potential moderate impacts	Up to 84 acres at a single facility, 163 acres total; potential moderate impacts	Up to 84 acres at a single facility, 163 acres total; potential moderate impacts
			Cultural Resources			
Current Storage Sites	Impacts unlikely	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1
Other Facilities[g]	Impacts dependent on location; avoid and mitigate	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

TABLE K.9 (Cont.)

Environmental Consequence	Case 1: 25% Use as Oxide; 25% Use as Metal; 50% Continued Storage	Case 2: 33% Use as Oxide; 33% Use as Metal; 33% Continued Storage	Case 3: 50% Use as Oxide; 50% Continued Storage	Case 4: 50% Use as Metal; 50% Continued Storage	Case 5: 50% Use as Oxide; 25% Use as Metal; 25% Continued Storage	Case 6: 25% Use as Oxide; 50% Use as Metal; 25% Continued Storage
	Environmental Justice					
All Sites	No disproportionately high and adverse impacts to minority or low-income populations in the general public during normal operations or from accidents; severe transportation accidents are unlikely and occur at random locations along routes; therefore, high and adverse disproportionate impacts to minority or low-income populations are unlikely	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1	Same as Case 1

[a] For purposes of comparison, estimates of human health effects (e.g., LCFs) have been rounded to the nearest whole number. Accident probabilities are the estimated frequencies multiplied by the number of years of operations.

[b] Chemical exposures for involved workers during normal operations would depend in part on facility designs. The workplace environment would be monitored to ensure that airborne chemical concentrations were below applicable exposure limits.

[c] Accidents with probabilities of occurrence greater than 0.01 per year.

[d] On the basis of calculations performed for the PEIS, the accidents that are listed in this table have been found to have the highest consequences of all the accidents analyzed for the given frequency range. In general, accidents that have lower probabilities have higher consequences.

[e] In addition to noninvolved worker impacts, chemical and radiological exposures for involved workers under accident conditions (workers within 100 m of a release) would depend in part on facility designs and other factors (see Section 4.3.2.1).

[f] Accidents with probabilities of occurrence from 0.0001 per year to less than 0.000001 per year.

[g] Other facilities are facilities for conversion, long-term storage, manufacturing, and disposal.

[h] The guideline concentration used for comparison with estimated surface water and groundwater uranium concentrations is the proposed EPA maximum contaminant level of 20 µg/L; this value is an applicable standard for water "at the tap" of the user, and is not a directly applicable standard for surface water or groundwater (no such standard exists). The guideline concentration used for comparison with estimated soil uranium concentrations is a health-based guideline value for residential settings of 230 µg/g.

Footnotes continue on next page

TABLE K.9 (Cont.)

Footnotes (Cont.)

i Other parameters evaluated include changes in runoff, floodplain encroachment, groundwater recharge, depth to groundwater, direction of groundwater flow, soil permeability, and erosion potential.

j For construction, direct jobs and direct income are reported for the peak construction year. For operations, direct jobs and income are presented as annual averages, except for continued storage, which is reported for the peak year of operations.

k Habitat losses and land-use acreages given as maximum for a single site or facility, conversion facilities would also need to establish protective action distances encompassing 960 acres around the facility.

l Resources evaluated include construction materials (e.g., concrete, steel, special coatings), fuel, electricity, process chemicals, and containers (e.g., drums and cylinders).

Notation: CaF_2 = calcium fluoride; HF = hydrogen fluoride; LCF = latent cancer fatality; LLW = low-level radioactive waste; LLMW = low-level mixed waste; MEI = maximally exposed individual; MgF_2 = magnesium fluoride; NH_3 = ammonia; UF_6 = uranium hexafluoride.

TABLE K.10 Summary of Potential Environmental Consequences of Example 50% Use as Oxide, 50% Use as Metal Combination Alternative

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
	Human Health and Safety — Normal Facility Operations[a]
Radiation Exposure	
Involved workers	
Annual dose to individual workers	Monitored to be maintained within maximum regulatory limit of 5 rem/yr or lower
Total health effects among involved workers (1999–2039)	1 to 2 additional LCFs
Noninvolved workers	
Annual dose to noninvolved worker MEI (all facilities)	Well within public health standards (i.e., less than maximum dose limit of 100 mrem/yr)
Total health effects among noninvolved workers (1999–2039)	0 additional LCFs from routine site emissions
General public	
Annual dose to general public MEI (all facilities)	Well within public health standards (i.e., less than maximum dose limit of 100 mrem/yr)
Total health effects among members of the public (1999–2039)	0 additional LCFs from routine site emissions
Chemical Exposure of Concern (concern = hazard index > 1)	
Noninvolved worker MEI[b]	No (Hazard Index <1)
General public MEI	No (Hazard Index <1)
	Human Health and Safety — Facility Accidents[a]
Physical Hazards from Construction and Operations (involved and noninvolved workers)	
On-the-job fatalities and injuries (1999–2039)	3–4 fatalities; 2,300–3,100 injuries
Accidents Involving Releases of Chemicals or Radiation: Cylinder Accidents at Current Storage Sites	
Likely Cylinder Accidents[c]	
Accident[d]	Corroded cylinder spill, dry conditions
Release	Uranium, HF
Estimated frequency	~ 1 in 10 years
Accident probability (1999–2039)	3 potential accidents

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
Human Health and Safety — Facility Accidents[a] (Cont.)	
Consequences (per accident)	
Chemical exposure – public	No adverse effects
Chemical exposure – Noninvolved workers[e]	
Adverse effects	70
Irreversible adverse effects	3
Fatalities	0
Radiation exposure – public	
Dose to MEI	3 mrem
Risk of LCF	1 in 1 million
Total dose to population	0.4 person-rem
Total LCFs	0
Radiation exposure – Noninvolved workers[e]	
Dose to MEI	77 mrem
Risk of LCF	3 in 100,000
Total dose to workers	2.2 person-rem
Total LCFs	0
Accident risk (consequence times probability)	
General public	0 fatalities
Noninvolved workers	0 fatalities
Low Frequency-High Consequence Cylinder Accidents[f]	
Accident[d]	Vehicle-induced fire, 3 full cylinders (high for adverse effects); corroded cylinder spill, wet conditions (high for irreversible adverse effects)
Release	Uranium, HF
Estimated frequency	~ 1 in 100,000 years
Accident probability (1999–2039)	~ 1 chance in 2,500
Consequences (per accident)	
Chemical exposure – public	
Adverse effects	1,900
Irreversible adverse effects	1
Fatalities	0
Chemical exposure – noninvolved workers[e]	
Adverse effects	1,000
Irreversible adverse effects	300
Fatalities	3
Radiation exposure – public	
Dose to MEI	15 mrem
Risk of LCF	7 in 1 million
Total dose to population	1 person-rem
Total LCFs	0

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
Human Health and Safety — Facility Accidents[a] (Cont.)	
Radiation exposure – noninvolved workers[e]	
Dose to MEI	20 mrem
Risk of LCF	8 in 1 million
Total dose to workers	16 person-rem
Total LCFs	0
Accident risk (consequence times probability)	
General public	0 fatalities
Noninvolved workers	0 fatalities
Accidents Involving Releases of Chemicals or Radiation: Low Frequency-High Consequence Accidents at All Facilities[f]	
Chemical accident[d]	HF or NH_3 tank rupture
Release	HF, NH_3
Accident location	Conversion site
Estimated frequency	< 1 in 1 million years
Accident probability (1999–2039)	1 chance in 50,000 (over 20 years)
Consequences (per accident)	
Chemical exposure – public	
Adverse effects	41,000
Irreversible adverse effects	1,700
Fatalities	30
Chemical exposure – noninvolved workers[e]	
Adverse effects	1,100
Irreversible adverse effects	440
Fatalities	4
Accident risk (consequence times probability)	
General public	0 fatalities
Noninvolved workers	0 fatalities
Radiological accident	Earthquake damage to storage building at conversion site
Release	Uranium (UO_2)
Accident location	Conversion site
Estimated frequency	1 in 100,000 years
Accident probability (1999–2039)	1 chance in 5,000 (over 20 years)

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
Human Health and Safety — Facility Accidents[a] (Cont.)	
Consequences (per accident)	
Radiation exposure – public	
Dose to MEI	68 mrem
Risk of LCF	3 in 100,000
Total dose to population	5 person-rem
Total LCFs	0
Radiation exposure – noninvolved workers[e]	
Dose to MEI	2,300 mrem
Risk of LCF	9 in 10,000
Total dose to workers	210 person-rem
Total LCFs	0
Accident risk (consequence times probability)	
General public	0 LCFs
Noninvolved workers	0 LCFs
Human Health and Safety — Transportation[a]	
Major Materials Assumed to Be Transported between Sites	UF_6 cylinders Uranium oxide Uranium metal HF (if produced) CaF_2 (if produced) NH_3 MgF_2 LLW/LLMW Casks
Normal Operations	
Fatalities from exposure to vehicle exhaust and external radiation	0 to 1
Maximum radiation exposure to a person along a route (MEI)	Less than 0.1 mrem
Traffic Accident Fatalities (1999–2039) (physical hazards, unrelated to cargo)	
Maximum use of trucks	4 fatalities
Maximum use of rail	1 fatality

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
Human Health and Safety — Transportation[a] (Cont.)	
Traffic Accidents Involving Releases of Radiation or Chemicals	
Low Frequeny-High Consequence Cylinder Accidents	
Accident	Urban rail accident involving 4 cylinders
Release	Uranium, HF
Accident probability (1999–2039)	1 chance in 10,000
Consequences (per accident)	
Chemical exposure –All workers and members of general public	
Irreversible adverse effects	4
Fatalities	0
Radiation exposure – All workers and members of general public	
Total LCFs	60
Accident Risk (consequence times probability)	
Workers and general public	0 fatalities
Low Frequency-High Consequence Accidents with All Other Materials	
Accident	Urban rail accident involving anhydrous HF
Release	Anhydrous HF
Accident probability (1999–2039)	1 chance in 30,000
Consequences (per accident)	
Chemical exposure – workers and members of general public	
Irreversible adverse effects	30,000
Fatalities	300
Accident risk (consequence times probability)	
Irreversible adverse effects	1
Fatalities	0

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
	Air Quality
Current Storage Sites	
Pollutant emissions during construction	Maximum 24-hour PM_{10} concentration up to 95% of standard; other criteria pollutants well within standards
Pollutant emissions during operations	Maximum 24-hour HF concentration up to 93% of standard at K-25; HF concentrations well within standards at other sites; criteria pollutants well within standards at all sites
Other Facilities[g]	
Pollutant emissions during construction and operations	Maximum 24-hour PM_{10} concentration up to 90% of standard; other pollutant emissions well within standards (all less than 30% of standards)
	Water and Soil[h]
Current Storage Sites	
Surface water, groundwater, and soil quality	Uranium concentrations would remain within guideline levels
Other parameters[i]	No change
Other Facilities[g]	
Surface water, groundwater, and soil quality	Site-dependent; contaminant concentrations could be kept within guideline levels
Other parameters[i]	Site-dependent; none to moderate impacts
	Socioeconomics[j]
Current Storage Sites	
Continued storage	**Jobs:** 30 peak year, construction; 120 per year over 20 years operations **Income:** \$1.4 million peak year, construction; \$6 million per year over 20 years operations

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
	Socioeconomics*[j] *(Cont.)
Cylinder preparation	**Jobs:** 0–580 peak year, preoperations; 300–490 per year over 20 years operations **Income:** \$0–26 million peak year, preoperations; \$19–25 million per year over 20 years operations
Other Facilities[g]	
Conversion	**Jobs:** 710–1,100 peak year, construction; 520–770 per year over 20 years operations **Income:** \$29–47 million peak year, construction; \$31–44 million per year over 20 years operations
Manufacturing	**Jobs:** 300 peak year, construction; 540 per year over 20 years operations **Income:** \$14 million peak year, construction; \$38 million per year over 20 years operations
	Ecology
Current Storage Sites	
Habitat loss[k]	Up to 28 acres; negligible to potential moderate impacts
Concentrations of chemical or radioactive materials	Below harmful levels; potential site-specific effects from facility or transportation accidents
Wetlands and threatened or endangered species	None to negligible impacts
Other Facilities[g]	
Habitat loss[k]	**Conversion:** Up to 29 acres at a single site; total of 56 acres; potential moderate impacts to vegetation and wildlife **Manufacturing:** Up to 84 acres at a single site; total of 170 acres; potential moderate to large impacts to vegetation and wildlife

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
	Ecology (Cont.)
Concentrations of chemical or radioactive materials	Below harmful levels; potential site-specific effects from facility or transportation accidents
Wetlands and threatened or endangered species	Site-dependent; avoid or mitigate
	Waste Management
Current Storage Sites	LLW: no impacts LLMW: potential moderate impacts with respect to current waste generation at Paducah (> 20%); negligible impacts with respect to Portsmouth, K-25, or nationwide waste generation
Other Facilities[g]	
Conversion	Potential moderate impacts to current nationwide LLW generation for CaF_2 (if produced and not used) and MgF_2 as LLW (if required); potential moderate impact to site waste generation for CaF_2 and MgF_2 as nonhazardous solid waste
Manufacturing	Negligible impacts with respect to current regional or nationwide waste generation
	Resource Requirements[l]
All Sites	No effects on local, regional, or national availability of materials are expected
	Land Use
Current Storage Sites	Up to 28 acres; less than 1% of available land; negligible impacts
Other Facilities[g]	
Conversion	Up to 29 acres at a single site; total of up to 56 acres; potential moderate impacts
Manufacturing	Up to 84 acres at a single site; total of 170 acres; potential moderate impacts

TABLE K.10 (Cont.)

Environmental Consequence	Case 7: 50% Use as Uranium Oxide; 50% Use as Metal
	Cultural Resources
Current Storage Sites	Impacts unlikely
Other Facilities[g]	Impacts dependent on location; avoid and mitigate
	Environmental Justice
All Sites	No disproportionately high and adverse impacts to minority or low-income populations in the general public during normal operations or from accidents; severe transportation accidents are unlikely and occur randomly along routes; therefore, high and adverse impacts to minority or low-income populations are unlikely

[a] For purposes of comparison, estimates of human health effects (e.g., LCFs) have been rounded to the nearest whole number. Accident probabilities are the estimated frequencies multiplied by the number of years of operation.

[b] Chemical exposures for involved workers during normal operations would depend in part on of facility designs. The workplace environment would be monitored to ensure that airborne chemical concentrations were below applicable exposure limits.

[c] Accidents with probabilities of occurrence greater than 0.01 per year.

[d] On the basis of calculations performed for the PEIS, the accidents that are listed in this table have been found to have the highest consequences of all the accidents analyzed for the given frequency range. In general, accidents that have lower probabilities have higher consequences.

[e] In addition to noninvolved worker impacts, chemical and radiological exposures for involved workers (workers within 100 m of a release) under accident conditions would depend in part on facility designs and other factors (see Section 4.3.2.1).

[f] Accidents with probabilities of occurrence from 0.0001 per year to less than 0.000001 per year.

[g] Other facilities are facilities for conversion and manufacturing.

[h] The guideline concentration used for comparison with estimated surface water and groundwater uranium concentrations is the proposed U.S. Environmental Protection Agency (EPA) maximum contaminant level of 20 µg/L (EPA 1996); this value is an applicable standard for water "at the tap" of the user and is not a directly applicable standard for surface water or groundwater (no such standard exists). The guideline concentration used for comparison with estimated soil uranium concentrations is a health-based guideline value for residential settings of 230 µg/g.

[i] Other parameters evaluated include changes in runoff, floodplain encroachment, groundwater recharge, depth to groundwater, direction of groundwater flow, soil permeability, and erosion potential.

Footnotes continue on next page

TABLE K.10 (Cont.)

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[j] For construction, direct jobs and direct income are reported for peak construction year. For operations, direct jobs and income are presented as annual averages, except for continued storage, which is reported for the peak year of operations.

[k] Habitat losses and land-use acreages given as maximum for a single site or facility. Conversion facilities would also need to establish protective action distances encompassing 960 acres around the facility.

[l] Resources evaluated include construction materials (e.g., concrete, steel, special coatings), fuel, electricity, process chemicals, and containers (e.g., drums and cylinders).

Notation: CaF_2 = calcium fluoride; HF = hydrogen fluoride; LCF = latent cancer fatality; LLW = low-level radioactive waste; LLMW = low-level mixed waste; MEI = maximally exposed individual; MgF_2 = magnesium fluoride; NH_3 = ammonia; PM_{10} = particulate matter with a mean diameter of 10 µm or less; UF_6 = uranium hexafluoride.

K.8 REFERENCES FOR APPENDIX K

EPA: see U.S. Environmental Protection Agency.

Lawrence Livermore National Laboratory, 1996, unpublished data, preliminary cost estimate reports and details, Livermore, Calif., Feb.–Sept.

Lawrence Livermore National Laboratory, 1997a, *Depleted Uranium Hexafluoride Management Program; the Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride*, UCRL-AR-124080, Volumes I and II, prepared by Lawrence Livermore National Laboratory, Science Applications International Corporation, Bechtel, and Lockheed Martin Energy Systems for U.S. Department of Energy.

Lawrence Livermore National Laboratory, 1997b, *Cost Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride,* UCRL-AR-127650, prepared by Lawrence Livermore National Laboratory, Livermore, Calif., for U.S. Department of Energy, May.

LLNL: see Lawrence Livermore National Laboratory.

Tomasko, D., 1997, *Water and Soil Impact Analyses in Support of the Depleted Uranium Hexafluoride Programmatic Environmental Impact Statement*, attachment to memorandum from D. Tomasko (Argonne National Laboratory, Argonne, Ill.) to H.I. Avci (Argonne National Laboratory, Argonne, Ill.), May 21.

U.S. Environmental Protection Agency, 1996, *Drinking Water Regulations and Health Advisories*, EPA 882-B-96-002, Office of Water, Washington, D.C., Oct., pp. 1-11.

APPENDIX L:

RESPONSES TO COMMENTS RECEIVED DURING THE SCOPING PROCESS FOR THE PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR ALTERNATIVE STRATEGIES FOR THE LONG-TERM MANAGEMENT AND USE OF DEPLETED URANIUM HEXAFLUORIDE

CONTENTS (APPENDIX L)

NOTATION (APPENDIX L)

The following is a list of acronyms and abbreviations used in this appendix.

ACRONYMS AND ABBREVIATIONS

General

CEQ	Council on Environmental Quality
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
HEU	highly enriched uranium
LEU	low-enriched uranium
MOX	mixed oxide (fuel)
NEPA	*National Environmental Policy Act*
NOI	Notice of Intent
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
USEC	United States Enrichment Corporation

Chemicals

UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
U_3O_8	triuranium octaoxide (uranyl uranate)

APPENDIX L:

RESPONSES TO COMMENTS RECEIVED DURING THE SCOPING PROCESS FOR THE PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR ALTERNATIVE STRATEGIES FOR THE LONG-TERM MANAGEMENT AND USE OF DEPLETED URANIUM HEXAFLUORIDE

L.1 SCOPING PROCESS

The U.S. Department of Energy (DOE) issued a Notice of Intent (NOI) to prepare a programmatic environmental impact statement (PEIS) for depleted uranium hexafluoride (UF_6) on January 25, 1996, in the *Federal Register* (61 FR 2239). In addition, a letter from the project manager, copies of the NOI, a scoping comment form, and a fact sheet entitled "Overview of the Programmatic Environmental Impact Statement" were mailed to 3,800 individuals. These individuals were identified by personnel at the three DOE sites currently used for storage of depleted UF_6 and through the DOE stakeholder mailing list. Two public scoping meetings were held in the vicinity of each current storage site — Paducah, Kentucky (February 13, 1996); Oak Ridge, Tennessee (February 15, 1996); and Portsmouth, Ohio (February 20, 1996).

Information relevant to both the project and the *National Environmental Policy Act* (NEPA) process was provided through development of an Internet Home Page that includes an overview of the project, fact sheets, NEPA and Council on Environmental Quality (CEQ) regulations, access to an Internet Environmental Law Library, and links to DOE's NEPA Web and CEQ's NEPA Net. Provision for commenting on the scope of the PEIS was provided in the overview presentation on the Home Page. The computer-based overview presentation is available on CD-ROM and was available on computers at the scoping meetings. The public was also provided with a mechanism for commenting directly while viewing the computer program.

Approximately 300 persons attended the scoping meetings. DOE staff were present at information tables to receive comments directly from the attendees. In addition, the public was able to provide comments on the scope of the PEIS by filling out the scoping comment form (hardcopy or via the CD-ROM program); by mailing or faxing comments to the program office; and/or by sending an electronic mail message via the Internet. The majority of the 235 individual comments received during the scoping period were received at the scoping meetings.

The public comments are discussed in detail in the next section. All comments received at the scoping meetings, both written and oral, have been categorized as to subject and made available over the World Wide Web at the following address: http://www.ead.anl.gov/uranium.html.

L.2 ENVIRONMENTAL IMPACT ISSUES IDENTIFIED IN SCOPING

The purpose of the scoping process is to determine the range of actions, alternatives, and significant impacts to be considered in the PEIS. The comments provided by the public during this scoping process were reviewed and organized into several groups on the basis of the issues raised. The majority of comments focused on the range of technical options to be considered by DOE in constructing alternative strategies. The issues and their disposition are summarized below.

L.2.1 Environment

General environmental issues relate to the need to consider a broad range of impacts to human health and safety, water, air, land, wildlife, and socioeconomics. More specific comments relate to the need to consider radioactive decay products, health effects of specific chemicals, and trace elements.

- **Comment**: The PEIS should evaluate in detail a broad range of impacts to water, air, land, wildlife, and socioeconomic resources from all options for storage, use, disposal, or conversion of depleted UF_6.

  Response: The PEIS will cover these technical areas at a level of detail appropriate for the programmatic analysis. Site-specific details related to potential locations for facilities will be provided in follow-on NEPA documents that will be prepared prior to any future siting decisions.

- **Comment**: The PEIS should use the TRIAD model developed by the National Oceanic and Atmosphere Administration for analyzing atmospheric dispersion and releases of depleted UF_6.

  Response: The TRIAD model was evaluated by the project team, who selected a more advanced model called HGSYSTEM for use in the PEIS.

- **Comment**: The PEIS should analyze the "worst-case scenarios" for health impacts to the public and workers from all options for storage, use, disposal, or conversion of depleted UF_6.

  Response: The PEIS will consider various accident scenarios based on preconceptual designs, including reasonably foreseeable low-probability, but potentially high-consequence, events. Accidents evaluated will include those with a probability of occurrence of 1 in 1 million (10^{-6}) to 1 in 10 million (10^{-7}).

- **Comment:** The PEIS should evaluate the risks to the public from unrestricted use of depleted uranium or fluoride materials.

  Response: Due to U.S. Nuclear Regulatory Commission (NRC) radioactive material licensing requirements, among other things, commercial depleted uranium applications with limited public access are envisioned. The PEIS will evaluate the use of depleted uranium as shielding for radioactive materials for which public access is controlled. In the future, it may be possible to get an exemption from the NRC for certain depleted uranium applications. The PEIS will evaluate risks to the general public from conversion of depleted UF_6, including production of hydrogen fluoride, which would be sold.

- **Comment:** The PEIS should compare and contrast health and safety risks from all options for depleted UF_6.

  Response: The PEIS will compare and contrast health and safety risks from representative options that encompass the types of health and safety impacts related to depleted UF_6 management. The range of parameters considered in the PEIS will encompass many specific technologies and commercial processes.

- **Comment:** The PEIS should address the trace elements and contaminants in depleted UF_6 and their potential impacts upon the environment.

  Response: Depleted UF_6 is a very pure material. Decay products of uranium, which are in trace quantities, will be included in the analysis.

- **Comment:** The PEIS should evaluate the cumulative impacts upon the likely locations for all options for depleted UF_6.

  Response: Cumulative impacts for "no action" and for cylinder preparation at the three storage sites will be considered in the PEIS, as appropriate. Cumulative impacts at locations for use, conversion, storage, or disposal will be discussed qualitatively, with references to tiered NEPA reviews. Site-specific analyses of cumulative impacts at specific use, conversion, storage, or disposal locations will be presented in follow-on NEPA analyses prior to any future specific siting decisions for these activities.

- **Comment:** The PEIS should evaluate the impacts upon the DOE waste management system for all depleted UF_6 options.

  Response: The PEIS will address disposal of depleted uranium as an oxide form at a low-level-waste facility. For options involving use or storage of depleted uranium, waste management will be analyzed for disposal or recycle of empty cylinders or by-products, as appropriate. This discussion will be based, in part, on DOE's *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DOE/EIS-0200-F).

- **Comment:** The PEIS should evaluate the long-term impacts from the changing chemistry and radioactive decay of uranium under the disposal options.

  Response: The PEIS analysis of disposal will include the decay products of uranium. It will be assumed that these products have a geochemical behavior similar to uranium.

L.2.2 Current Management of Depleted UF_6

Numerous comments were made regarding current management of cylinders at the Paducah site, the Portsmouth site, and the K-25 site on the Oak Ridge Reservation. These comments are summarized as follows:

- **Comment:** The PEIS should explain and evaluate current management of the cylinders at all three locations (Portsmouth, Paducah, and Oak Ridge).

  Response: The PEIS will provide a general discussion of cylinder management at the three sites and will consider the environmental impacts of "no action," which is continued cylinder management at the three sites.

- **Comment:** The PEIS should discuss the risks of current storage of the cylinders at all three locations.

  Response: The risks of current cylinder storage will be included in the PEIS.

L.2.3 Storage

A number of comments were received about alternative storage options, such as using old uranium mines or military installations. These comments are summarized below:

- **Comment:** The PEIS should evaluate a wide range of storage options, including storage in zinc mines in eastern Tennessee, transportation to a central location for consolidation, storage at retired military installations, stringent monitoring processes, smaller size or different containers, and buildings and low-maintenance storage arrangements.

Response: The PEIS will consider a range of storage options, including storage in a mine, in yards, in buildings, and in vaults. The impacts associated with consolidating all the material at one location compared with dispersing the material at several locations will also be evaluated. The impacts of storage at specific sites, such as a retired military base, will be evaluated in follow-on NEPA analyses conducted prior to any future siting decisions.

- **Comment:** The PEIS should clarify how storage in a mine would work.

  Response: Storage in a mine will be described at the level of a preconceptual design.

- **Comment:** The PEIS should clarify how building storage would work, particularly in terms of ventilation and air controls.

  Response: The PEIS will consider a generic design for building storage. General assumptions about building performance will be made for the purpose of health and safety analysis. Particular designs for climate control and ventilation will be considered in follow-on NEPA analysis conducted prior to a decision on facility design.

- **Comment:** The PEIS should explain how the cylinders will be stored for all options.

  Response: The PEIS will explain cylinder storage for each alternative, as appropriate.

L.2.4 Conversion

A number of suggestions for conversion were made for consideration in the PEIS, which are summarized as follows:

- **Comment:** The PEIS should consider technology-specific options for conversion, such as the Quantum-Catalytic Extraction Process™.

  Response: The PEIS will conduct analyses of representative technologies in determining the impacts of various management strategy alternatives. The conversion technology options analyzed will have a sufficient technical basis to develop meaningful preconceptual designs and estimates of the environmental data required for the PEIS analysis. After the decision is made on the long-term management strategy, specific technologies and sites will be considered in the second tier of the NEPA review process.

In response to the November 10, 1994, Request for Recommendations, a large number of promising conversion technologies were recommended that are in the early stages of design development or contain key aspects that are proprietary. In general, the proponents of these technologies believe that they offer process improvements and/or cost reductions compared with the more traditional processes. The Quantum-Catalytic Extraction Process™ is included in this category.

- **Comment**: The PEIS should consider other chemical forms for storage, such as metal, tetrafluoride, uranotile, and soddyite.

  Response: The PEIS will consider storage of depleted uranium as UF_6 and as the oxides triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2). The rationale for selection of these chemical forms for analysis will be presented in the PEIS. In general, storage as metal would require substantially less storage space than the other chemical forms under consideration. This advantage must be weighed against disadvantages such as higher conversion cost, lower stability, and the uncertainty of the suitability of the metal form for eventual disposal. Uranium tetrafluoride (UF_4), or greensalt, is an intermediate form in the process of converting UF_6 to metal or converting oxide to UF_6. It is significantly more chemically reactive than uranium oxides, and no use has been identified for UF_4. Conversion into uranium-bearing minerals such as soddyite and uranotile for subsequent storage or disposal would require development of the chemical conversion process as well as examination of the suitability of such forms for storage or disposal.

- **Comment**: The PEIS should evaluate only conversion options at existing facilities, not at new facilities.

  Response: The PEIS is a programmatic-level document and will analyze conversion at representative facilities. The siting issues associated with building and operating conversion facilities at specific locations will be included in follow-on NEPA analyses conducted prior to any future siting decisions. The use of existing facilities would be evaluated when future siting decisions were made after the Record of Decision for this PEIS.

- **Comment**: The PEIS should consider shipping depleted UF_6 to Britain or France for processing.

Response: This PEIS addresses depleted UF_6 located in the continental United States and evaluates the transportation of all uranium products on a per-mile basis using U.S. national statistics. This could be applied to transport of the material to any port in the 48 contiguous states for shipment overseas. A decision as to vendors or processes for conversion of depleted UF_6 would be made after the Record of Decision for this strategic PEIS. At that time, NEPA analysis of international vendors or processes might be appropriate.

L.2.5 Use of Depleted UF_6

Many comments and suggestions were made about the use of depleted UF_6 after conversion, which are summarized as follows:

- **Comment:** The PEIS should consider the recovery (reenrichment) of uranium-235 from depleted UF_6.

  Response: Recovery of uranium-235 is a potential reason for storing depleted uranium. Long-term storage is a management option that would preserve some or all of the inventory of depleted UF_6 for use. The viability of refeeding depleted UF_6 is a function of the isotopic assay of depleted UF_6 and many uncertain factors in the future, such as uranium ore price, separative work cost, and demand. The PEIS will briefly discuss these factors.

- **Comment:** The PEIS should evaluate recycling cylinders as scrap steel.

  Response: The PEIS will address the issue of including empty cylinders in ongoing studies related to DOE's Recycle 2000 initiative for recycle of scrap metals.

- **Comment:** The PEIS should include use of depleted uranium in concrete as aggregate, including use in Hanford reactors.

  Response: Use of depleted uranium oxide in concrete for shielding purposes will be analyzed in the PEIS. The analysis of this technology at specific facilities will be addressed in follow-on NEPA analyses prior to any siting decisions.

- **Comment:** The PEIS should include use of depleted uranium for backfill material in spent nuclear fuel packages.

  Response: The PEIS will evaluate the use of depleted uranium for spent nuclear fuel shielding applications.

- **Comment:** The PEIS should include use of depleted uranium for blending highly enriched uranium (HEU) to produce low-enriched uranium (LEU) or for use in mixed-oxide (MOX) fuels.

  Response: The no action alternative and long-term storage alternatives preserve these options for later use of depleted uranium for blending HEU into LEU or in MOX nuclear fuels (see *Storage and Disposition of Weapons-Usable Fissile Materials, Final Programmatic Environmental Impact Statement*, DOE/EIS-0229, December 1996). The quantity of depleted uranium potentially used for these applications would be very small compared with the representative uses that will be considered in the Depleted UF_6 PEIS.

- **Comment:** The PEIS should evaluate separate uses for depleted uranium and fluorine.

  Response: The PEIS will analyze representative uses for the depleted uranium from depleted UF_6 and will assume that the fluorine from depleted UF_6 has commercial value as anhydrous hydrogen fluoride and would be sold.

- **Comment:** The PEIS should evaluate only feasible and attainable uses.

  Response: The representative options to be evaluated in the PEIS were selected because they are feasible and attainable in a reasonable time frame.

- **Comment:** The extent of uses in the general population and demands for such uses should be analyzed in the PEIS.

  Response: The demand for depleted UF_6 is an economic issue that is outside the scope of the PEIS because the need for management of depleted UF_6 is based on prudent management, not on demand. Such issues as the demand for depleted uranium — including existing data on potential uses, percent of inventory for current or future uses, and optimal form of depleted uranium for use — are discussed in the engineering and cost analysis reports, which will also support the decision on management strategy.

- **Comment:** The PEIS should consider the assay level (e.g., 0.2% uranium-235 compared with 0.4% uranium-235) as a discriminator for uses.

  Response: A homogeneous assay level is being assumed for this programmatic-level analysis. At a later time, when disposition of individual cylinders is decided, assay level will become an important consideration.

L.2.6 Cost

A number of issues were expressed with regard to costs. Some indicated that DOE should not spend a lot of money on the problem of depleted UF_6 management, whereas others indicated that costs and benefits of the options should be considered. Specific comments were grouped into the following major issues:

- **Comment:** The PEIS should present and evaluate costs for all depleted UF_6 management options. Costs should be kept to a minimum by using proven processing procedures, selling by-products, and using competitive bid processes.

  Response: A separate cost analysis report is being prepared, which will be considered in preparing the Record of Decision. The PEIS will discuss costs as they relate to socioeconomic impacts.

- **Comment:** The PEIS should explain the value of the materials in economic terms.

  Response: The value of the materials is being addressed separately in a cost analysis report.

L.2.7 Disposal

The disposal options for depleted UF_6 elicited comments regarding waste definitions and waste disposal options, as follows:

- **Comment:** The PEIS needs to evaluate the impacts of disposal in the event that depleted UF_6 were to be classified as a transuranic waste.

  Response: Depleted UF_6 is a source material. For purposes of the disposal options, it is being assumed that depleted UF_6 will be converted into an oxide and, in oxide form, will be treated as a low-level waste. The PEIS will evaluate the health and environmental impacts of such disposal.

- **Comment:** The PEIS should consider additional options for disposal, such as disposal in sedimentary formations on the ocean floor, vitrification with the molten glass or other techniques, disposal in old missile silos, or returning UF_6 to its original state and to its original source (i.e., uranium mines).

  Response: The PEIS will analyze a set of options that are anticipated to bound most possibilities for disposal. However, some options are subject to institutional constraints, are speculative in nature, are in an unknown state of technical development, or have exorbitant costs. The PEIS will describe why certain options were considered in less detail or were judged to be unreasonable.

L.2.8 Transportation

It was suggested that barge transportation be considered in the PEIS:

- **Comment**: The PEIS should fully evaluate the transportation impacts from all options for depleted UF_6, especially barge transport (including shipping standards and emergency preparedness).

  Response: Transportation impacts will be discussed generally in the PEIS for representative routes and representative sites. Decisions on the locations of potential conversion, manufacturing, storage, or disposal facilities would be made after the Record of Decision for this PEIS. At that future time, barge transportation might be appropriate and would be analyzed in any accompanying NEPA documentation. This PEIS will include a qualitative discussion of the results of analyses conducted for other NEPA documents that compare barge transport to truck and rail transport, and a statement that future studies or NEPA analyses supporting siting decisions for conversion, manufacturing, storage, or disposal facilities will consider the transport of depleted UF_6 by barge, as appropriate.

L.2.9 Policy

Policy issues are higher level issues that could affect the whole PEIS structure and content. A number of these issues were included in the public comments, as follows:

- **Comment**: The PEIS should explain how its decisions fit within the context of other DOE decisions on materials.

  Response: The PEIS will explain how the programmatic depleted UF_6 decision (how best to manage depleted UF_6 in the future) fits with other related DOE decisions and programs currently under consideration.

- **Comment**: The PEIS should evaluate treatment, storage, and disposal of depleted UF_6 as a waste material.

Response: Depleted UF_6 is a source material. The disposal options considered in the PEIS assume conversion of depleted UF_6 to an oxide, with subsequent disposal. Uranium oxides are generally suitable forms for storage (and disposal). The impacts associated with both storage and disposal of U_3O_8 and UO_2 will be examined.

- **Comment:** The PEIS should explain the time frames for the options and provide some support for those time frames.

  Response: Time frames for the various phases of the options will be discussed in general terms within the PEIS.

- **Comment:** The PEIS should evaluate all depleted UF_6 materials in the United States, both existing stocks and those for the foreseeable future.

  Response: The PEIS will analyze a depleted UF_6 inventory accumulated by DOE and its predecessor agencies at Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. The analysis will cover the period from 1945 through July 1, 1993, at which time the United States Enrichment Corporation (USEC), a government-owned corporation, was created to operate the Paducah and Portsmouth gaseous diffusion plants. Discussions between the Office of Management and Budget, USEC, and DOE are continuing regarding a Memorandum of Agreement, as provided in Section 3109(a)(2) of the USEC Privatization Act. This Memorandum of Agreement will allocate liabilities that arise from USEC's operations prior to privatization among DOE, USEC, the United States Government, and the new private corporation, including those liabilities arising from the disposal of depleted uranium, currently stored as UF_6, that was generated by USEC. The draft PEIS will address DOE's role in the management of this depleted uranium consistent with the terms of the Memorandum of Agreement. Because the new corporation will be responsible for the management of depleted UF_6 that it generates after privatization, DOE's role in the future disposal of this material is uncertain and speculative at this time. DOE will fulfill its NEPA responsibilities, as appropriate, when decisions are made in the future regarding the disposition of depleted UF_6 generated by the private corporation.

- **Comment:** DOE should include the NRC, the U.S. Environmental Protection Agency (EPA), and the Nevada Test Site in the discussions of disposal options for depleted UF_6.

  Response: Other federal agencies, including NRC and EPA, will be consulted during the PEIS comment process. The Nevada Test Site, a DOE site, will be asked for comments.

- **Comment:** The PEIS should analyze options for privatizing all facilities considered in the options for depleted UF_6.

  Response: The privatization of facilities will be considered qualitatively in the PEIS.

- **Comment:** DOE needs to identify the sources of funds that will be used for this program.

  Response: The issue of program funding is outside the scope of this NEPA analysis, which addresses impacts to the natural and human environment.

L.2.10 Other Issues

Other issues are not easily categorized and therefore have been placed at the end of the discussion of topics brought up during public scoping. These issues are summarized as follows:

- **Comment:** The PEIS should consider what other nations such as Japan and France have done with regard to depleted UF_6.

  Response: Part of the engineering development for options considered technologies in other countries.

- **Comment:** The PEIS should fully explain the need for taking any actions for depleted UF_6.

  Response: The PEIS will explain the purpose and need for the action.

- **Comment:** The PEIS should have a smaller list of alternatives so that the decisions and impacts can be clearly understood.

  Response: The PEIS will attempt to minimize the list of options and alternatives in order to clearly lay out the environmental effects for the decision makers and the public.

APPENDIX M:

CONTRACTOR DISCLOSURE STATEMENT

APPENDIX M:

CONTRACTOR DISCLOSURE STATEMENT

Argonne National Laboratory (ANL) is the contractor assisting DOE in preparing the PEIS for depleted UF_6. DOE is responsible for reviewing and evaluating the information and determining the appropriateness and adequacy of incorporating any data, analyses, or results in the PEIS. DOE determines the scope and content of the PEIS and supporting documents and will furnish direction to ANL, as appropriate, in preparing these documents.

The Council on Environmental Quality's Regulations (40 CFR 1506.5(c)), which have been adopted by the U.S. Department of Energy (10 CFR Part 1021), require contractors who will prepare an Environmental Impact Statement to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for the purposes of this disclosure is defined in the March 23, 1981, "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations," 46 *Federal Register* 18026-18028 at Questions 17a and 17b. Financial or other interest in the outcome of the project includes "any financial benefit such as promise of future construction or design work on the project, as well as indirect benefits the consultant is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients"), 46 *Federal Register* 18026-18038 at 10831.

In accordance with these regulations, Argonne National Laboratory hereby certifies that it has no financial or other interest in the outcome of the project.

Certified by:

Anthony J Dvorak
Signature

Anthony J. Dvorak
Name

Director, Environmental Assessment Division
Title

September 6, 1996
Date

APPENDIX N:

PUBLIC LAW 105-204

PUBLIC LAW 105–204—JULY 21, 1998 112 STAT. 681

Public Law 105–204
105th Congress

An Act

To require the Secretary of Energy to submit to Congress a plan to ensure that all amounts accrued on the books of the United States Enrichment Corporation for the disposition of depleted uranium hexafluoride will be used to treat and recycle depleted uranium hexafluoride.

July 21, 1998
[S. 2316]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. UNITED STATES ENRICHMENT CORPORATION.

President.
Ohio.

(a) PLAN.—The Secretary of Energy shall prepare, and the President shall include in the budget request for fiscal year 2000, a plan and proposed legislation to ensure that all amounts accrued on the books of the United States Enrichment Corporation for the disposition of depleted uranium hexafluoride will be used to commence construction of, not later than January 31, 2004, and to operate, an onsite facility at each of the gaseous diffusion plants at Paducah, Kentucky, and Portsmouth, Ohio, to treat and recycle depleted uranium hexafluoride consistent with the National Environmental Policy Act.

(b) LIMITATION.—Notwithstanding the privatization of the United States Enrichment Corporation and notwithstanding any other provision of law (including the repeal of chapters 22 through 26 of the Atomic Energy Act of 1954 (42 U.S.C. 2297 et seq.) made by section 3116(a)(1) of the United States Enrichment Corporation Privatization Act (104 Stat. 1321–349), no amounts described in subsection (a) shall be withdrawn from the United States Enrichment Corporation Fund established by section 1308 of the Atomic Energy Act of 1954 (42 U.S.C. 2297b–7) or the Working Capital Account established under section 1316 of the Atomic Energy Act of 1954 (42 U.S.C. 2297b–15) until the date that is 1 year after the date on which the President submits to Congress the budget request for fiscal year 2000.

APPENDIX O:

SUMMARY OF THE ENGINEERING ANALYSIS REPORT*

*Please note that this entire Appendix O has been added after the public comment period.

UCRL-ID-124080

Depleted Uranium Hexafluoride Management Program

Summary of the ENGINEERING ANALYSIS REPORT for the Long-term Management of Depleted Uranium Hexafluoride

Prepared for the Department of Energy by
Lawrence Livermore National Laboratory

September 1997

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

Summary of the ENGINEERING ANALYSIS REPORT for the Long-Term Management of Depleted Uranium Hexafluoride

Note: This summary condenses and simplifies a number of technical issues and ideas. To obtain a fuller understanding of particular issues and ideas, the reader is urged to consult the complete *Engineering Analysis Report.*

1. Introduction

The Department of Energy is reviewing ideas for the long-term management and use of its depleted uranium hexafluoride.

The Department of Energy (DOE) owns about 560,000 metric tons (over a billion pounds) of depleted uranium hexafluoride (UF_6). This material is contained in steel cylinders located in storage yards near Paducah, Kentucky, and Portsmouth, Ohio, and at the East Tennessee Technology Park (formerly the K-25 Site) in Oak Ridge, Tennessee.

Uranium hexafluoride (UF_6) is a compound of one part uranium to six parts fluorine. At room temperature, it is a white solid similar to rock salt. It is usually measured in metric tons (MT). One MT equals about 2200 pounds.

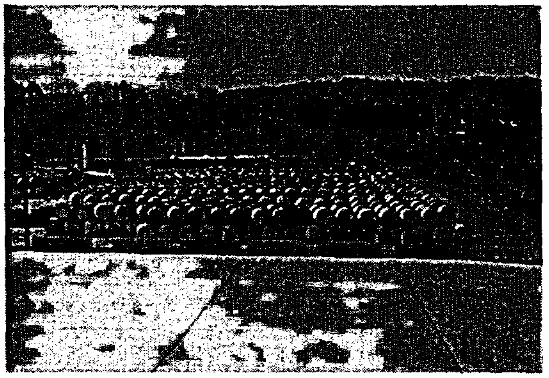
On November 10, 1994, DOE issued a Request for Recommendations and an Advance Notice of Intent in the *Federal Register* (59 FR 56324 and 56325) to initiate the consideration of alternative strategies for the long-term management and use of depleted UF_6. The first part of the Depleted UF_6 Management Program consists of engineering, cost, and environmental impact studies. Part one will conclude with the selection of a long-term management plan, or strategy. Part two will carry out the selected strategy.

1.1 Background—What Is Depleted Uranium Hexafluoride?

Uranium is made up of several different types of atoms. One of these, uranium-235 (U-235), can be made to split apart and release a large amount of energy. As found in nature, uranium contains only a very small amount of U-235. In order for uranium to produce significant amounts of energy, the percentage of U-235 must be increased. For example, uranium fuel for powerplants usually contains between three and five percent U-235, while natural uranium contains only about 0.71 percent U-235. Uranium with more than 0.71 percent U-235 is called "enriched" uranium.

The enrichment process used in the United States is gaseous diffusion. It was first used on a large scale in the 1940s as part of the Manhattan Project in Oak Ridge, Tennessee. Later, plants were also built at Paducah, Kentucky, and Portsmouth, Ohio. On July 1, 1993, DOE leased these two plants to the United States Enrichment Corporation, as required by the Energy Policy Act of 1992. Oak Ridge had stopped enriching uranium in 1985.

The first step in gaseous diffusion is to heat solid natural UF_6 until it becomes a gas. The UF_6 gas is repeatedly separated into two streams. Gradually, one stream gains U-235, while the other loses U-235. When the U-235 in this second stream has been reduced to between 0.2 and 0.4 percent, the depleted UF_6 is removed from processing and placed in storage. Between 1945 and July 1, 1993, about 560,000 MT of depleted UF_6 was stored at the three gaseous diffusion plant sites.



Depleted UF_6 is stored in cylinder yards like this one at Portsmouth.

Why is there so much depleted UF_6? For every pound of enriched uranium, between eight and nine pounds of depleted uranium are produced.

DOE's depleted UF_6 is stored in a partial vacuum inside steel cylinders. Most cylinders are about twelve feet long and 48 inches in diameter and hold between 9 and 12 MT of solid depleted UF_6. In all, there are 46,422 cylinders:

28,351 at Paducah
13,388 at Portsmouth
4,683 at Oak Ridge.

1.2 Selecting a Management Strategy

The current management strategy is to continue safe storage of the depleted UF_6 cylinders in the existing storage yards. Activities in this strategy include inspection, handling, monitoring, and maintenance, as needed, to keep the cylinders in good condition. Other possible management strategies could involve use of the depleted uranium, long-term storage, disposal, or some combination of these. A complete management strategy may include a number of different activities. Examples are transportation or conversion of the depleted UF_6 to another chemical form, such as an oxide or metal.

The *Draft Programmatic Environmental Impact Statement* (Draft PEIS) looks at alternative strategies for the long-term management of depleted UF_6. They include the current management strategy (the "No Action alternative"), two alternatives for long-term storage, two alternatives for use, and one for disposal. DOE's preferred alternative is to use 100 percent of the depleted uranium, either as uranium oxide or uranium metal, or a combination of both. The fluorine in the depleted UF_6 would also be used.

The *Engineering Analysis Report* contains the technical data on which the Draft PEIS and the cost analysis are based. The PEIS, the *Cost Analysis Report*, and the *Engineering Analysis Report* will help DOE select a management strategy. The Record of Decision is expected in 1998.

2. The Engineering Analysis Project

Data from the engineering analysis will help DOE compare the environmental impacts and costs of management strategy alternatives.

In November 1994, DOE asked members of the public, industry, and other government agencies to submit recommendations for the use or long-term management of depleted UF_6. Fifty-seven replies were received and reviewed by independent technical experts. The results were published in the *Technology Assessment Report* in June 1995. Most of the recommendations were judged to be feasible, or capable of being carried out now or in the near future. These ideas and technologies were analyzed in more detail.

The main part of the Engineering Analysis Project developed engineering data for the feasible technology options. The data include general layouts for facilities, descriptions of processes, and analysis of hazards.

2.1 Work Breakdown Structure

A work breakdown structure shows the work that will need to be done on a project, moving from a general level to more and more detailed levels. It provides an orderly way to analyze and compare complex management strategies. Figure 1 shows the first three levels of the work breakdown structure for depleted UF_6 management.

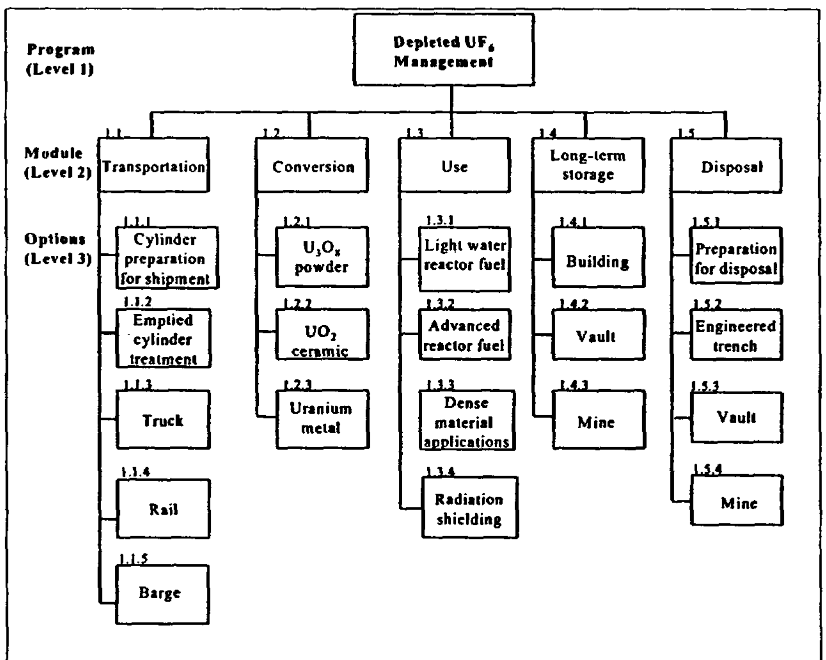


Figure 1. Depleted UF_6 Management Work Breakdown Structure, Showing Modules (Level 2) and Options (Level 3)

The recommendations received early in the Engineering Analysis Project fell into several general categories. These general categories are called modules because they are the most basic building blocks for management strategies (see Level 2 in Figure 1). The modules are transportation, conversion, use, long-term storage, and disposal. Most management strategy alternatives combine two or more of these five modules. For example, conversion of the depleted UF_6 to another chemical form is involved in the use and disposal alternatives and in one of the long-term storage alternatives. Transportation of materials occurs in all strategies except the No Action alternative.

In each module, there are various options (Level 3 in Figure 1), or different ways of doing things. For example, in the long-term storage module there are three different options for the type of facility in which the depleted uranium could be stored: building, vault, and mine.

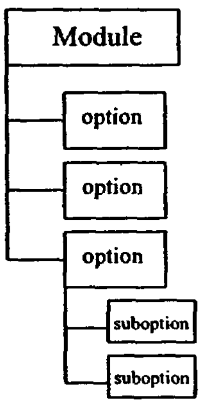


Figure 2. Modules are broken down into options. Options are broken down into suboptions.

The next level of detail after options is called suboptions. For example, the long-term storage facility types are further broken down by the forms of depleted uranium which might be stored in each. Figure 2 shows the general relationship among modules, options, and suboptions.

The *Engineering Analysis Report* focuses on technology options and suboptions. Data for the options and suboptions can be combined to provide overall data for alternatives. To get a better idea of how options and suboptions were linked together to form management strategy alternatives, see Figure 3, which appears at the end of this Summary.

2.2 Methodology

The *Engineering Analysis Report* contains 13 Engineering Data Input Reports, covering the specific options and suboptions named in the unshaded boxes in Table 1. These are the options and suboptions which were analyzed in depth. Options and suboptions which were analyzed in less detail are discussed in Chapter 4 of the *Engineering Analysis Report.*

Each Data Input Report includes layouts for facilities, descriptions of processes, estimates of wastes and emissions, estimates of resources and workers needed, hazard assessments, accident scenarios, and transportation information. The data are estimates based on an early stage of design. More detailed data for specific technologies will be developed in the second part of the Program.

Table 1. Options and Suboptions for the Various Modules

(Note: shaded boxes are principal options and suboptions analyzed in less detail)

Transportation Module: Options	Transportation Module: Suboptions
Cylinder preparation for shipment	• Current cylinders • Over-container • Transfer facility
Emptied cylinder treatment	• Cylinder treatment facility
Truck	• UF_6 in current or new cylinders or over-container • Depleted uranium conversion products • Metal or oxide shields • By-products, chemicals, and wastes
Rail	(same suboptions as Truck)
Barge	• UF_6 in current or new cylinders or over-container

Conversion Module: Options	Conversion Module: Suboptions
U_3O_8 powder	• Dry process with AHF* • Dry process with HF neutralization
UO_2 ceramic	• Dry process with AHF* • Dry process with HF neutralization • Wet process (gelation) with AHF*
U metal	• Batch reduction • Continuous reduction

Use Module: Options	Use Module: Suboptions
Light water reactor fuel	• Re-enrichment
Advanced reactor fuel	• Breeder and other fast reactors
Dense material applications	• Existing applications: munitions, armor, counter-weights, ballasts • New applications
Radiation shielding	• UO_2 • U metal

Long-Term Storage Module: Options	Long-Term Storage Module: Suboptions
Building	• UF_6 • U_3O_8 • UO_2
Vault	• U_3O_8 • UO_2
Mine	• UF_6 • U_3O_8 • UO_2

Disposal Module: Options	Disposal Module: Suboptions
Preparation for disposal	• U_3O_8 cemented • UO_2 cemented • U_3O_8 bulk • UO_2 bulk
Engineered trench	• U_3O_8 cemented • UO_2 cemented • U_3O_8 bulk • UO_2 bulk
Vault	• U_3O_8 cemented • UO_2 cemented • U_3O_8 bulk • UO_2 bulk
Mine	• U_3O_8 cemented • UO_2 cemented • U_3O_8 bulk • UO_2 bulk

* Anhydrous hydrogen fluoride (HF)

Examples of assumptions used in the engineering analysis:

- Total time for project: 20 years.
- Processing rate: 28,000 MT (60 million pounds) of depleted UF_6 per year.
- Each of the different forms of depleted uranium would always have the same bulk density and the same type of packaging for transportation.
- Facilities are newly built on previously unused sites.

To make it easier to compare the different options and suboptions, data were based on certain common assumptions.

Estimates based on different processing rates (50 percent and 25 percent of the assumed rate) were made for several technologies and are included in Chapter 8 of the *Engineering Analysis Report*.

Each Engineering Data Input Report includes its own analysis of reasonably foreseeable accidents involving radiological or hazardous materials. There is also an accident analysis in Chapter 7 which discusses two particular types of accidents: (1) accidents associated with depleted UF_6 cylinder handling and storage and (2) accidents which would have significant hazardous and/or radiological material releases but have a very low probability. In general, the higher the consequences of an accident, the less frequently such an accident is likely to occur. The accidents discussed in Chapter 7 are what are called "incredible" accidents, which means that their likelihood of occurrence is between once in one million years and once in ten million years.

The *Engineering Analysis Report* also includes discussions of license, permit, and regulatory requirements and changes in regulations for the transportation of depleted UF_6 cylinders.

3. Summary of Options Analyzed in Depth

Feasible technologies for which data could be developed were analyzed in depth.

Options which were judged to be feasible in the *Technology Assessment Report* were analyzed in depth. These are general types of technologies, but they have enough technical basis to allow engineers to develop the data needed for estimates of environmental impacts and costs. Additional options, most of which are at an earlier stage of development, were also considered. These are described in the *Engineering Analysis Report* but are analyzed in less detail.

This section describes the technology options and suboptions which were analyzed in depth. They are grouped into the five modules in the work breakdown structure. The modules are printed in boldface type and the options are underlined. Table 1 gives an overall summary of the information.

3.1 Transportation Module

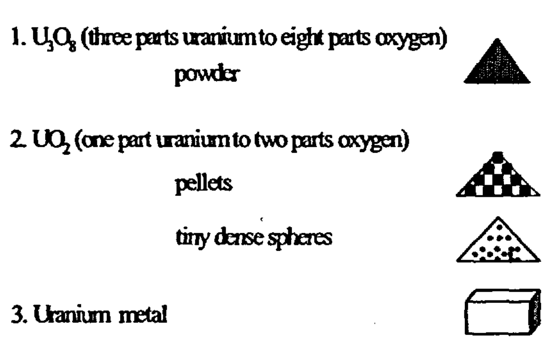
All of the Engineering Data Input Reports include a discussion of transportation of materials by both truck and rail. Materials which would be transported would include depleted UF_6, depleted uranium in other chemical forms (after conversion), manufactured products for use, and other materials such as by-products and wastes.

Two transportation options, preparation of depleted UF_6 cylinders for shipment and treatment of emptied cylinders, are analyzed in their own individual Data Input Reports.

<u>Cylinder Preparation for Shipment.</u> All alternatives in the Draft PEIS, except for the No Action alternative, assume that depleted UF_6 cylinders will be moved from their current locations. Transportation of cylinders is regulated by the Department of Transportation (DOT). These regulations involve (1) the amount of depleted UF_6 inside the cylinder, (2) the pressure inside the cylinder, and (3) the condition of the cylinder, especially the thickness of the steel walls. Some cylinders meet the DOT requirements and would require minimal preparation; however, some would require additional work to meet DOT regulations.

There are two suboptions for preparing these nonconforming cylinders. In the overcontainer suboption, the cylinder would be placed inside a container which meets DOT regulations. In the transfer facility suboption, the depleted UF_6 would be transferred to a new cylinder. Using the overcontainer would require less handling and produce less waste. It would also avoid the construction of a special facility. A transfer facility would be expected to have greater impacts, but it could be used in developing an alternative for long-term storage of depleted UF_6 in new cylinders.

<u>Emptied Cylinder Treatment.</u> In most of the management strategies, the depleted UF_6 would be taken out of the cylinders and converted to another chemical form. Any depleted UF_6 left in the emptied cylinder (called the "heel") would be washed out with water. After the water evaporates, the mixture of depleted uranium and fluorine would be converted to solid uranium oxide and hydrogen fluoride



UF_6 Conversion Products

(HF) gas. Hydrogen fluoride gas is corrosive. To neutralize it, or make it harmless, lime would be added, forming calcium fluoride (CaF_2). The analysis assumes that the cleaned, emptied cylinders will be stored as scrap metal.

3.2 Conversion Module

Most management strategy alternatives require converting the depleted UF_6 to another chemical form. Three other chemical forms of depleted uranium are analyzed in depth: triuranium octaoxide (U_3O_8) powder, uranium dioxide (UO_2) ceramic, and uranium metal. The oxides are compounds of uranium and oxygen. Because the oxides are very stable and slow to dissolve in water, they are presently the preferred forms for long-term storage and disposal. Very dense depleted UO_2 and depleted uranium metal are preferred for use in shielding for spent nuclear fuel because they are good at absorbing the kind of radiation called gamma rays. Depleted uranium metal is preferred for most dense material applications, which need high density and mass.

Conversion starts by heating solid depleted UF_6 to produce a gas. All the conversion processes being analyzed in depth produce large quantities of hydrogen fluoride (HF). Uranium hexafluoride and HF are the most significant chemical hazards to the environment and workers during conversion. The designs for the conversion process buildings and the HF storage buildings use reinforced concrete for added safety. Temperatures in the HF storage buildings would be kept between 45° and 55° Fahrenheit. This would prevent the HF from becoming a gas that a worker might inhale in case of a spill.

The conversion facilities would be expected to operate about 7000 hours per year. They would have enough outdoor storage for one month's supply of full depleted UF_6 cylinders. There would also be enough indoor storage space for three months' supply of nearly empty cylinders. This would allow time for short-lived radioactive products in the heel to decay before the cylinders are treated or shipped off site. The facilities would include storage for one month's production of the new depleted uranium form and one month's production of HF.

<u>U_3O_8 Option.</u> Two suboptions are analyzed for converting depleted UF_6 to depleted U_3O_8. (The conversion of UF_6 to an oxide is referred to as "defluorination" because fluorine atoms are removed.) Both suboptions use a two-step process in which depleted UF_6 reacts with steam at high temperatures. This is called a "dry" process, as opposed to "wet" processes, in which the main reactions occur in water. The process produces depleted U_3O_8 in fluffy powder form and concentrated HF, which is about 70 percent HF and about 30 percent water. After the depleted U_3O_8 is compacted, it would have a bulk or packing density of about 3 grams per cubic centimeter (about 1 3/4 ounces per cubic inch).

The first U_3O_8 suboption uses distillation to reduce the water content in the concentrated HF to one percent or less. The resulting HF vapor is called anhydrous HF (AHF), meaning that it has very little water. It is expected that the uranium content will be low enough that the AHF can be sold for use. The second U_3O_8 suboption would neutralize the HF to produce CaF_2 for sale or disposal.

<u>UO_2 Option.</u> Uranium dioxide in the ceramic form is very dense. Depending on the shape and size of its particles, the UO_2 will generally be two to three times denser than compacted U_3O_8 powder. The denser product would require less space for storage or disposal. The denser form could also be used in depleted uranium concrete for radiation shielding.

There are three suboptions for converting depleted UF_6 to depleted UO_2. Two of them use a dry process (similar to the one described above for U_3O_8) to make UO_2 powder. The UO_2 powder is pressed into pellets about 2 centimeters (3/4 inch) in diameter. To increase their density, the pellets are then heated at about 1700° centigrade (about 3092° Fahrenheit). The furnaces are expected to be larger than those currently used in nuclear fuel manufacturing plants. One of the dry process suboptions provides an AHF by-product and the other neutralizes the HF.

The third technology suboption is based on a "wet" process which produces dense depleted UO_2 in the form of very small spheres of a millimeter (about 1/20 inches) or less in diameter. These tiny particles can be packed very close. The process, called "gelation," dissolves U_3O_8 in an acid. Various chemicals are added and the solution is fed through nozzles which break it into small droplets. These droplets are then decomposed into jelly-like spheres of depleted uranium oxide. These are further processed and finally heated at high temperatures. Gelation has yet to be proven as an industrial process; therefore, the technological uncertainties with the wet process are greater than with the more developed dry processes.

<u>Uranium Metal Option.</u> The analysis considers two suboptions, a batch process and a continuous process, for converting depleted UF_6 to depleted uranium metal. Both processes start by combining depleted UF_6 with hydrogen to make depleted uranium tetrafluoride (UF_4) and AHF. In the second step, magnesium (Mg) is used to remove the fluorine from the UF_4 (known as "reduction"). Because it uses a metal, Mg, and takes place at high temperatures, this process is called "metallothermic reduction."

The batch process is the standard industrial process. A mixture of depleted UF_4 and Mg metal is heated in a sealed steel container until it forms liquid depleted uranium metal and a magnesium fluoride (MgF_2) by-product. The denser uranium metal settles to the bottom and the MgF_2 collects on top. After the container has cooled, the solid depleted uranium metal and MgF_2 are removed and separated from each other. The by-product contains some uranium. Without further treatment, it would have to be disposed of as a radioactive low-level waste. The design for the batch process includes a step for removing uranium from the MgF_2. It is assumed that, after this step, the MgF_2 could be disposed of as a nonradioactive, nonhazardous solid waste.

The other suboption analyzed in depth is the continuous process, which is currently being developed. In this process, depleted UF_4 and Mg are continuously fed into a heated container. The dense liquid uranium metal settles to the bottom and is removed. The liquid MgF_2 forms a middle layer and is separately removed. The liquid Mg floats on the top.

The continuous process has three possible advantages over the batch process: (1) a higher processing rate, (2) a lower level of uranium in the by-product, and (3) a liquid depleted uranium product which could be directly formed into an end product. The early design assumes that the amount of uranium in the by-product will be small enough that a decontamination step would be unnecessary. Based on the design, the continuous process would have a lower cost than the batch process. However, since the continuous process is still being developed, the technological uncertainties are greater.

3.3 Use Module

The use option analyzed in depth is to make depleted uranium into a shielding material to put around spent nuclear fuel. The fuel in nuclear powerplants has to be replaced every so often. The used-up, or spent, nuclear fuel (SNF) is still radioactive and must be shielded. The *Engineering Analysis Report* analyzes two suboptions for use as radiation shielding, but this is only one of several possible uses for depleted uranium. Other uses include fuel for light (regular) water reactors or advanced reactors and dense material applications. Section 4.3 discusses use options which were analyzed in less detail. The two radiation shielding suboptions analyzed in depth are examples of possible uses.

<u>Radiation Shielding Option - UO_2 Suboption.</u> This suboption would use depleted uranium in the form of UO_2 pellets. These dense pellets can be used instead of gravel to make concrete shielding for SNF storage containers. Depleted uranium concrete, also known as DUCRETE™, provides shielding with less weight and bulk than regular concrete. It might also be usable in overcontainers for SNF disposal, but this use has yet to be developed.

In the designs for storage containers, the depleted uranium concrete is enclosed inside stainless steel. The shielding manufacturer receives partly finished steel shells and other parts and puts the containers together in one building. In another building, where radiological materials can be handled, depleted UO_2 pellets from a conversion plant are combined with sand, cement, and water, and the depleted uranium concrete is poured between the stainless steel shells. After the cement hardens, the container is completed.

<u>Radiation Shielding Option - Uranium Metal Suboption.</u> This suboption would manufacture depleted uranium metal into shields for use inside a multi-purpose unit system. A multi-purpose unit is a container that would provide confinement of SNF during storage, transportation, and disposal.

In this design, the manufacturer receives depleted uranium metal (or alloy), partly completed stainless steel or metal alloy shells, and other pieces to enclose the uranium metal. The containers are put together in one building. In a separate building, where radiological materials can be handled, the depleted uranium metal is melted and poured between the steel or alloy shells. After the depleted uranium metal cools, the container is completed.

3.4 Long-Term Storage Module

Long-term storage means that the depleted uranium could be used at some later date. Three long-term storage options are analyzed in depth: (1) storage in a building, (2) storage in a below ground vault, and (3) storage in a mine. The suboptions are the chemical forms in which the depleted uranium is stored. Three forms are considered for storage in buildings or mines: UF_6, U_3O_8, and UO_2. Two forms are considered for storage in vaults: U_3O_8 and UO_2. These chemical forms have very different bulk densities. A denser product takes up less space and could therefore cost less to store. This analysis assumes that the tiny, dense UO_2 spheres produced by the gelation process would need the least storage space and U_3O_8 powder would need the most storage space.

The building option uses metal framed buildings for storage. The below ground vault would be made of reinforced concrete with a steel roof supported by trusses. Storage in a mine would use underground tunnels.

3.5 Disposal Module

The engineering analysis for this module considers three options for disposal: (1) disposal in an engineered trench, (2) disposal in a below ground vault, and (3) disposal in a mine. The engineered trench is an 8-meter (26-foot) deep trench covered with a sloping cap of closely packed clay and other barriers. This option would work best in drier areas.

A form which is stable and slow to dissolve is preferred for disposal. Therefore, the chemical forms analyzed for disposal are the oxides, U_3O_8 and UO_2. In addition, the depleted uranium oxide powder or pellets may either be mixed with cement before disposal or disposed of in bulk form inside drums. Altogether, there are four waste form suboptions: (1) cemented U_3O_8, (2) cemented UO_2, (3) bulk U_3O_8, and (4) bulk UO_2. Each disposal facility option is analyzed for all four waste forms.

The analysis covers a wide range of conditions, including variations in the climate and geology of possible disposal locations and variations in the amount of disposal space needed. Cemented U_3O_8 requires the most space because U_3O_8 is less dense than UO_2 and because the cement adds to the mass. The form requiring the least space for disposal is bulk UO_2.

All the disposal facility designs include a waste form facility (preparation for disposal option). This is where the depleted uranium oxide is received from the conversion plant. For cemented waste forms, preparation would include mixing the oxide with cement, repackaging it in new or recycled drums, and allowing it to harden. Bulk waste forms would require less preparation.

4. Summary of Principal Options and Technologies Analyzed in Less Detail

Technologies analyzed in less detail in this part of the Program are preserved for the second part of the Program.

Most of the options considered in the engineering analysis were replies to DOE's Request for Recommendations. The technologies discussed in Section 3 are general types, but they have enough technical basis to allow engineers to develop data which can be used to estimate environmental impacts and costs. A number of other technologies were also recommended. These options are promising but are analyzed in less detail for one or more of the following reasons: they are in earlier stages of design or development; they would take more time than the 20-year schedule assumed in this analysis; they are proprietary; they involve uses of depleted uranium which are already in practice.

Technologies analyzed in less detail during the first part of the Depleted Uranium Hexafluoride Program are still available for consideration for the next part of the Program. These technologies are briefly described below. The options and suboptions analyzed in depth are general enough that the estimates made could cover a variety of specific technologies.

4.1 Transportation Module

Transport by barge was considered. However, at this time the locations for most activities are unknown and the possibility of using barge transportation is uncertain. All three gaseous diffusion plant sites mainly use ground transportation. Except for the East Tennessee Technology Park, facilities for using barges would have to be developed.

4.2 Conversion Module

Many good ideas for conversion technologies were submitted. In general, they are in the early stages of design or development. Some of them are also proprietary. When more fully developed, these processes might offer such advantages as more flexibility, fewer processing steps, reduced environmental impacts, lower costs, and higher profits.

Uranium Oxide Suboptions. A number of responses recommended using the well-known dry process for converting UF_6 to an oxide with an AHF by-product. There were also several recommendations for newer technologies with important features. One example uses a wet process to convert depleted UF_6 to an intermediate compound which is then heated and converted to depleted U_3O_8. Anhydrous hydrogen fluoride is directly produced. Another technology uses a liquid metal such as iron to speed up the decomposition of depleted UF_6. Afterwards, uranium oxides and AHF are formed in a single step.

Two general processes were recommended which have a by-product other than AHF. One makes a depleted uranium oxide and a solid aluminum and fluoride compound which is used in the production of aluminum metal. The other technology uses depleted UF_6 as a source of fluorine for making hydrofluorocarbons. Hydrofluorocarbons can be used instead of chlorofluorocarbons, which are believed to reduce ozone in the atmosphere.

Uranium Metal Suboptions. As discussed earlier, the more familiar processes for producing depleted uranium metal also produce large amounts of MgF_2 waste. A different type of technology called plasma dissociation avoids the MgF_2 waste stream. In this one-step process, a gas such as argon is heated to more than 5000° centigrade or 9032° Fahrenheit, using electrical energy. At these very high temperatures, depleted UF_6 is broken down into uranium and fluorine atoms. After the gas cools, the fluorine atoms react with added hydrogen to produce AHF, and the uranium atoms combine with each other to form depleted uranium metal.

This process would avoid the uncertainties about the disposal of MgF_2. It would also bring in more money from the sale of AHF, because all the fluorine in the depleted UF_6 is recovered. This process is in the early stage of development.

Several other recommendations contained improved ideas for removing uranium from MgF_2. These recommendations also had suggestions for the recovery and possible use of by-products (for example, converting the MgF_2 to AHF). These advanced treatment technologies could reduce waste and be more economical.

4.3 Use Module

Three use options are analyzed in less detail. These are (1) use as fuel for a light (regular) water power reactor, (2) use as fuel for an advanced power reactor, and (3) use in dense material applications. A number of people recommended these uses. The fuel options are analyzed in less detail because they would take a long time to use up significant amounts of depleted UF_6. The long-term storage options discussed in the *Engineering Analysis Report* and the preferred alternative in the Draft PEIS would allow these, and other, uses to be reconsidered in the future. The environmental impacts of existing or new dense material applications are expected to be similar to those of the uranium metal radiation shielding option which is analyzed in depth.

Light Water Reactor Fuel Option. The main suboption for this use would involve re-enriching the depleted UF_6, that is, increasing the percentage of U-235. The technologies that are used for enriching natural uranium could also be used to enrich depleted uranium. If all the U-235 in DOE's depleted UF_6 were recovered, it could provide fuel for the equivalent of about 100 power reactors operating for 10 years apiece. Re-enriching depleted uranium would save natural uranium resources and avoid the impacts of uranium mining and milling. However, only a small amount of the depleted uranium would actually be converted into enriched uranium. Most of the depleted uranium (over 90 percent) would remain after processing, and would still require management.

It is uncertain when re-enrichment would be economical. Continued storage preserves the possibility for the future, particularly for depleted uranium which has more than 0.3 percent U-235.

Another possible use of depleted uranium in light water reactors could involve converting the depleted UF_6 to UO_2. The depleted UO_2 could then be mixed with plutonium oxide to produce mixed oxide fuel. However, this suboption would use up only a very small amount of the depleted UF_6.

Advanced Reactor Fuel Option. One reason why DOE considered the depleted UF_6 a valuable resource was its potential use in advanced reactors of the future. One such type of reactor, called a fast breeder reactor, actually produces additional fuel. Used in an advanced reactor, the depleted uranium could provide hundreds of years of electrical power at the present U.S. production rate. However, this option would require a change in national policy, which is based on a once-through fuel cycle. In addition, since the advanced reactors are very fuel efficient, they would use up only a small amount of depleted uranium.

Dense Material Applications Option. Dense material applications include some ways in which depleted uranium metal is already being used, such as armor-piercing munitions, vehicle armor, ballasts in aircraft, and weights for stabilizing machinery. Other new uses were suggested in responses to the Request for Recommendations. These include energy storage flywheels (heavy metal wheels that store energy and make shafts rotate evenly), drill collars to keep oil well drill shafts centered, and explosives for the petroleum industry to open up the earth around natural gas and oil wells. Future dense material applications are uncertain at this time. The long-term storage options discussed in the *Engineering Analysis Report* and the preferred alternative in the Draft PEIS would allow these, and other, uses to be considered in the future.

4.4 Long-Term Storage Module

Storage as depleted uranium metal and storage as depleted uranium tetrafluoride (UF_4) were considered but analyzed in less detail. Uranium metal bars would require much less space than oxides or UF_6, but it costs much more to convert depleted UF_6 to metal than to U_3O_8. In addition, there are safety issues with storage as metal. Unless it is protected, bulk uranium metal slowly corrodes. In air, the metal flakes can catch fire and release energy rapidly. The reaction between moisture and uranium metal creates hydrogen, which could explode if it collected in closed storage containers. For these reasons, storage as metal would require special packaging and more supervision.

Depleted uranium in the form of UF_4 was considered for long-term storage or disposal but was analyzed in less detail. Conversion to UF_4 is fairly simple and inexpensive, but another conversion step would probably be required before the material could be used. Depleted UF_4 is less chemically reactive than depleted UF_6 but more reactive than the oxides and it would take up about the same amount of storage or disposal space as depleted U_3O_8. Other forms are more generally recommended for disposal.

4.5 Disposal Module

Disposal as depleted UF_6, depleted uranium metal, and depleted UF_4 were considered but analyzed in less detail. Regulations restrict the chemical forms that can be used for disposal. Reactive waste forms such as the fluorides and metal are specifically excluded by the Nevada Test Site and Hanford and by DOE Orders.

The *Engineering Analysis Report* analyzes bulk and cemented waste forms in detail. Another possible suboption is vitrification, in which depleted uranium oxide would be enclosed in glass. The basic technology is developed (for disposal of high-level radioactive waste), but other types of waste preparation are generally preferred for depleted uranium. Vitrified waste would require more space for disposal. In addition, a vitrification facility would be more complicated and costly to build and operate than a cementing facility.

5. Roadmap for Integration of Engineering Data Input Reports into Long-Term Management Strategy Alternatives

Figure 3 shows how complete management strategy alternatives can be put together from the options and suboptions analyzed in the *Engineering Analysis Report.* Depleted UF_6 stored in the cylinder yards at Paducah, Portsmouth, and Oak Ridge (the current management strategy) is shown at the left of the figure. Moving from left to right are the transportation, conversion, use, long-term storage, and disposal modules (work breakdown structure Level 2).

The options and suboptions which are analyzed in depth are shown as blocks below the module names. The arrows on the chart indicate the flow of material for the various management strategies. Offsite transportation may be required between one option or suboption and another. This is shown by the small boxes marked "T." Activities such as construction of facilities, transportation of other materials and by-products, and transportation and disposal of wastes are also included in the assessments of the management strategies.

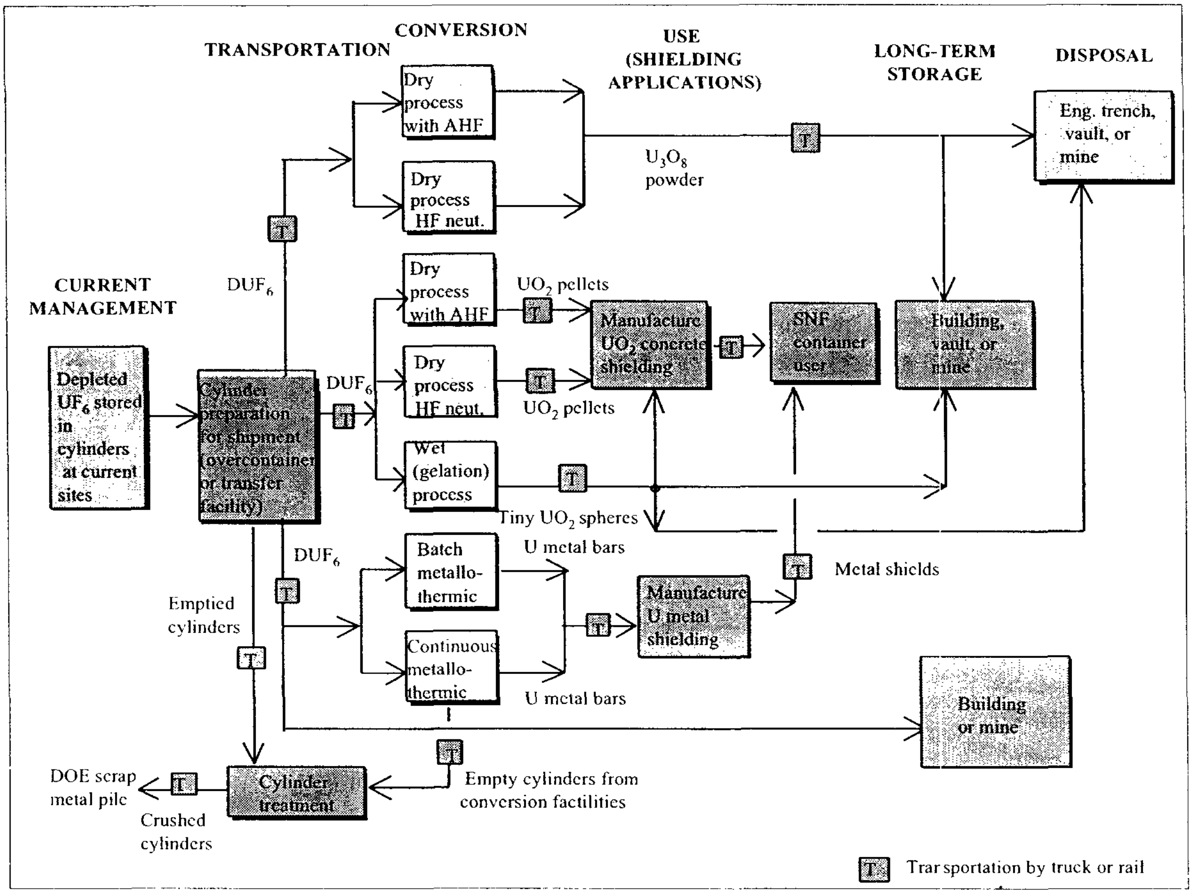


Figure 3. Flowchart for Developing Management Strategy Alternatives from Options and Suboptions

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