APPENDIX G:

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

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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

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 Total number of LCFs: 0.3 LCF	**Involved Workers:** Total collective dose: 240 person-rem Total number of LCFs: 0.1 LCF	**Involved Workers:** Total collective dose: 240 person-rem 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 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: 0.02 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: 0.02 rem Risk of LCF to MEI: 8×10^{-6} Collective dose: 7.5 person-rem Number of LCFs: 3×10^{-3}
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: 3×10^{-2} 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: 3×10^{-2} 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: 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 Total number of LCFs: 0.2 LCF **Noninvolved Workers:** Negligible impacts **General Public:** Negligible impacts	**Involved Workers:** Total collective dose: 540 person-rem Total number of LCFs: 0.2 LCF **Noninvolved Workers:** Negligible impacts **General Public:** Negligible impacts	**Involved Workers:** Total collective dose: 540 person-rem Total number of LCFs: 0.2 LCF **Noninvolved Workers:** Negligible impacts **General Public:** Negligible impacts
Human Health – Normal Operations: Chemical		
Noninvolved Workers: No impacts **General Public:** No impacts	**Noninvolved Workers:** No impacts **General Public:** No impacts	**Noninvolved Workers:** No impacts **General Public:** No impacts
Human Health – Accidents: Radiological		
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 Risk of LCF to MEI: 3×10^{-3} Collective dose: 700 person-rem Number of LCFs: 0.3 **General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem Risk of LCF to MEI: 1×10^{-4} Collective dose to population within 50 miles: 17 person-rem Number of LCFs in population within 50 miles: 9×10^{-3} LCF	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 Risk of LCF to MEI: 3×10^{-3} Collective dose: 700 person-rem Number of LCFs: 0.3 **General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem Risk of LCF to MEI: 1×10^{-4} Collective dose to population within 50 miles: 17 person-rem Number of LCFs in population within 50 miles: 9×10^{-3} LCF	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 Risk of LCF to MEI: 3×10^{-3} Collective dose: 700 person-rem Number of LCFs: 0.3 **General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.23 rem Risk of LCF to MEI: 1×10^{-4} Collective dose to population within 50 miles: 17 person-rem 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

	Latent Cancer Risk to Receptor					
	Involved Worker[a]		Noninvolved Workers[b]		General Public[c]	
Option	Average Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk (risk/yr)	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

		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)
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]

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
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]

		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
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	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	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	Averaging Time	Pollutant Concentration ($\mu g/m^3$) Construction	Pollutant Concentration ($\mu g/m^3$) 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} µg/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

		Requirements		
Option	Unit	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

Option	Unit	Physical Needs: Storage as U_3O_8	Physical Needs: 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

	Long-Term Storage as UF_6		Long-Term Storage as UO_2		Long-Term Storage as U_3O_8	
Parameter	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} µg/m^3 for HF, 5.3×10^{-7} µg/m^3 for UO_2F_2, and 1.8×10^{-9} µg/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

	Wastewater Volume (million L)			
Uranium Compound	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.

G.4 REFERENCES FOR APPENDIX G

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DOE: see U.S. Department of Energy.

EPA: see U.S. Environmental Protection Agency.

Folga, S., 1996, "Updated Information for the Long-Term Storage of UF_6 in Cylinder Yards Option in the DUF_6 PEIS," memorandum from S. Folga (Argonne National Laboratory, Argonne, Ill.) to DUF_6 PEIS Impacts Team (Argonne National Laboratory, Argonne, Ill.), Oct. 29.

Lawrence Livermore National Laboratory, 1997, *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.

LLNL: see Lawrence Livermore National Laboratory.

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